ABSTRACT

BATCH, DAKOTA DYLAN. Consumer Acceptance of Textile Products Dyed Using Recycled Food Waste. (Under the direction of Dr. Katherine Annett-Hitchcock).

Synthetic dye use is common in the textile industry due to its wide range of colors, pricing and ease of production. However, studies have shown that some synthetic dyes are harmful to human health and the environment surrounding synthetic dye facilities. Natural dye production is viewed as an alternative to the more toxic synthetic dyes, and is a growing industry that has the potential to utilize waste from other industries such as forestry and restaurants. Research in developing pre-consumer food waste as a form of alternative dye exists (Bechtold et al., 2006; Lee, 2006) and improvements in colorfastness and scalability can additionally assist in the area of food waste. The food industry is a heavy contributor to pollution, (Hall et al.,2009; United States Environmental Protection Agency, 2011) contributing to excess methane, CO_2 and other greenhouse gas emissions from decomposing food which impact global climate change (Hall et al., 2009). Allowing food to rot in a landfill creates methane gas, which is 28 to 36 times more effective than carbon dioxide at trapping heat in the atmosphere, which contributes to global warming. (Basic Information about Landfill Gas, 2019). By combining the waste of one industry with the productivity of another, this study explores a method of dyeing with food waste and its acceptability in the market.

Consumer Acceptance of Textile Products Dyed Using Recycled Food Waste

by
Dylan Dakota Batch

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master of Science

Textiles

Raleigh, North Carolina
2019

APPROVED BY:

Dr. Katherine Annett-Hitchcock
Committee Chair

Dr. Harold S. Freeman

Dr. Traci M. Lamar

DEDICATION

My research is dedicated to my mother, Fay Van Blake Batch. Thank you for imparting your wisdom, passion, love and patience. I am nothing without you. To my father Kenneth Herman Batch, thank you for always believing in me and giving me the courage to be myself. Finally, to the wonderful Marcia Cleaver who taught my stubborn 8-year-old self how to sew. I hope to one day pass on my passion for textiles, design, and the art of the craft to the next generation as you have with me.

BIOGRAPHY

Dylan Dakota Batch grew up in Odessa, Texas. When she was 8 years old, at the request of her mother, she begrudgingly took a quilting class and in turn learned how to sew. At that time, she did not realize how impactful that experience would be. She attended The University of Texas at Austin and graduated with a Bachelor's of Science in Textile and Apparel Design. Dakota studied abroad in India during her junior year of college, visiting apparel companies, textile dye houses and artisan hand block printing homes. She experienced firsthand, the global reach of the fashion industry and how it impacts millions of local individuals. She now strives to create a lasting change in the culture of textile and apparel production and teach an environmental mindset to future generations. Her experiences and education have enabled her to envision fashion that is beautiful while considering the environmental and economic consequences it creates on a region.

After two years of working for a non-profit, Dakota decided to return to school and receive her masters in textiles. She has had the wonderful opportunity of exploring many aspects of the design field she was not able to with her undergraduate career and is excited about the future opportunities her education will provide her

ACKNOWLEDGMENTS

The author would like to thank Dr. Katherine Annett-Hitchcock for being such a wonderful advisor. She has learned so much from and truly admires Dr. Kates' passion for social justice, equality and environmental issues. The author would also like to thank her wonderful committee members Dr. Harold S. Freeman and Dr. Traci Lamar for their invaluable input.

Special thanks to the managers of the collection sites (restaurants), Scott Curtner of Clark Dining Hall, Juan Esparza of AC Food, and Tammy Bullock of Starbucks in Talley Student Union. This project would be nothing without the amazing Mr. Jeffery Krauss and his team in the Pilot Laboratory and Mrs. Teresa White in the Physical Testing Laboratory in the Wilson College of Textiles. Thank you for your many hours of color matching help and explaining how to use the different machines, she is grateful. Many, many thanks to the statisticians, Tyler Brigman and Megan Moore for assisting in making sense of the collected data.

The author has had such an amazing support system throughout her years at North Carolina State University. Fellow graduate friends, amazingly supportive partner, Tyler Johnson and family. All are extremely loved and thank you for helping her make it to this point.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

Natural dyes have been used for centuries to colorize textile products. Cavemen applied fruits and berries to stain their skin and clothing, while darker colorants like Tyrian purple have been found on everything from weapons to royal attire (Cannon, Cannon, & Dalby-Quenet, 1994; Chenciner, 2000; Koren, 1993). Following the discovery of the first synthetic dye mauvine by chemist William Henry Perkin in the mid-19th century, there was a major industry shift toward the use of synthetic dyes worldwide (Garfield, 2002). Germany became the leading manufacturer of synthetic dyes in the early 20th century. Subsequently, countries like the United States, China, India and Japan imported thousands of tons of synthetic dyes every year (Morris & Travis, 1992). The natural dye industry experienced a brief resurgence due to a German ban on exports to Britain and its allies during World War I (Morris & Travis, 1992). The U.S textile industry utilized brazilwood, logwood and fustic natural dyes during this synthetic dye embargo. Additionally, the U.S began to invest and develop a domestic market of synthetic dye manufacturers. Following the end of the war, natural dyes would eventually fade away as a result of the growing U.S synthetic dye industry (Morris & Travis, 1992).

The popularity of natural dye is currently in a time of revival due to research on toxicity and potential carcinogenic properties of certain synthetic dyes (Lee, 2006). In addition to health risks, synthetic dyes can contribute to environmental issues such as hazardous compounds found in wastewater and marine life contamination (Yasheen & Scholz, 2018). Dye production and application is an area that is constantly being improved and using natural resources as an alternative to synthetics is being investigated (Raisanen, 2018). Current research supports the concept of using pre-consumer food waste (yellow onion skins, used coffee grounds, and avocado pits) from a restaurant to create a self-sustaining recycling system that flows from one industry to the other creating a circular economy (Bechtold et al., 2006). Research on color fastness properties (Bechtold et al., 2006), health benefits (Sathianarayanan et al., 2010) and environmental impact (Bechtold et al., 2006; Yusuf, Shabbir, & Mohammad, 2017) of these natural dyes is available; however, there is a gap in the research regarding consumer perceptions and/or acceptance of textile products dyed using this alternative plant material as a form of natural dye.

1.1. Statement of Purpose

The purpose of this research is to explore whether using pre-consumer food waste from plant material as a natural dye can produce a color in a textile product that is satisfactory to consumers. The study will also examine consumer perceptions of this textile product dyed using pre-consumer food waste compared to a synthetic dye, by measuring their desire for unique products and behaviors toward sustainability.

Conducting this research is timely, as more retailers are re-evaluating their bottom line (people, planet, and profit), investing in alternative and unique dyeing processes and working to reduce their environmental impact.

This study has two research objectives that were conducted in a two-phase process;

1. To extract natural dyes from pre-consumer food waste in order to dye a textile product.
2. To test consumer acceptance of the product using the Theory of Planned Behavior and Desire for Unique Consumer Products.

1.2. Definitions

1.2.1. Colorfastness. According to the American Association of Textile Chemists and Colorists (AATCC) the definition of colorfastness is the resistance of a material to change in any of its color characteristics, to transfer of its colorant(s) to adjacent materials or both, as a result of the exposure of the material to any environment that might be encountered during the processing, testing, storage or use of the material (AATCC Colorfastness to crocking, 2007).

1.2.2. Food waste. Food waste can be divided into two definable categories: Post-harvest (food loss and spoilage), which makes the food unfit for human consumption, and Post-consumer, which involves humans throwing away edible food (Grolleaud, 2002). For the purpose of this study, food waste will be used in the category of post-harvest food waste, i.e. food waste before it reaches humans for consumption.

1.2.3. Pre-consumer food waste. Pre-consumer food waste does not have a concrete definition. A study exploring food waste in dining halls used the operational definition of any organic material that is discarded during normal food preparation activities, e.g., peels, fat, bones, ends of fruits or vegetables (Costello, Birisci, & McGarvey, 2015). According to another study, pre-consumer food waste that is considered compostable typically includes fruit and vegetable scraps, eggshells, and coffee grounds (DeBell, Erlich, Mirza, & Runyon Sr., 2002).

1.2.4. Unique product. For the purpose of this research, a unique product will be defined as one that is scarce, innovative, customized, and/or outmoded (Lynn & Harris, 1997, p. 604).

1.3. Limitations

There were several limitations to this study. The sample population was limited in size and geographic location. This factor could influence data results, however, feasibility of reaching a larger population was difficult due to time and budget constraints.

The preserved nature of the plant material collected was not consistent. This limitation impacted depth of shade achieved in the dyed textile product.

The survey was conducted in the atrium in the Wilson College of Textiles, which has multiple windows and partial glass roof. A portion of the research survey required participants to evaluate and compare the color of dyed textile products. Weather inconsistencies such as cloudiness, might have affected how participants viewed and responded to the color.

1.4. Ethical Considerations

The survey used in this study was approved by the North Carolina State University Internal Review Board. This study qualified for a signed consent waiver, in which the consent form is provided to the participant, but signatures were not collected. Prior to beginning the survey, participants were informed of the research purpose, and told that participation was entirely voluntary, and compensation was a tote bag. There was no identifiable information collected during this study. Following the conclusion of the study, the collected information would be submitted to the principal investigator to be kept on record for five years per North Carolina State University requirement.

This survey contained minimal risks as no sensitive or identifying information was being collected. There were no direct benefits for participating. However, indirect benefits included, contributing to the ongoing research in the area of consumer behavior towards sustainable textile products. Participants might gain further understanding of textile dyeing process through the verbal explanation included in the survey.

CHAPTER 2
LITERATURE REVIEW

2.1. Natural Dyes

This section of the literature review will explore the history of natural dyes and how the dyes industry would transition with new developments improving colorfastness, global trade, and synthetic dye synthesis. Natural colorants will be discussed in addition to procedures for preparing, handling, extracting and applying natural dyes to textiles. Finally, natural and synthetic dyes health and environmental tradeoffs will be analyzed.

2.1.1. History of natural dyes.

Textile dyeing has been practiced since prehistoric times, using colorants extracted from both plant and animal sources, as well as inorganic materials (Koren, 1993). The foundation of natural dyeing most likely developed during the Neolithic Period, when people began to collect and store seeds and fruits (Chenciner, 2000). Plant materials found in nature were originally used for dyeing the body or for medical purposes, before being used for dyeing textiles (Forbes, 1964). The initial method of application included coating or mechanically pressing the plant material on the textile surface, which resulted in poor wash and color fastness of the textile (Robinson, 1969). The earliest examples of this process were found in the Cave of the Warrior, located near Jericho, Palestine which dates back to the late 5th century B.C. The textiles were decorated with black bands made from organic materials like gum, resin, asphalt, or bitumen that were smeared and pressed into the textile. During the Bronze (3rd C. B.C.) and Iron Ages (1st C. B.C.) significant innovations were made in textile dyeing using chemical processes. Textiles found in Timna, Israel suggest the use of an advanced dyeing technique in which a chemical bond between the dye and the fiber eventually produced a high-quality dyed textile with color that was resistant to laundering and exposure to the sun (Sukenik et al., 2017). There is evidence that madder, a natural dye derived from plant root, was used to dye cloth found in Egyptian tombs dating back to the pre-dynastic era, 3rd century A.D. on King Tutankhamun's belt and other textiles found in his tomb (Koren, 1993; Wickens, 1990). Bright yellow linen mummy binding found in the Tomb of the Two Brothers (about 2000 B.C.) was analyzed and reported to have been dyed with safflower, one of the world's oldest crops (Koren, 1993). Tyrian Purple, a natural dye derived from the secretion of rock snails, was discovered by the Phoenicians around 1500 B.C. Tyrian purple played an integral role in the history and development of several civilizations on the shores of the Mediterranean. This area was comprised of Palestine and Syria, which was called Canaan, meaning land of the purple (McLaren, 1986). Tyrian Purple was undoubtedly the most renowned and highly prized of all ancient dyes. It stood as a symbol of wealth and distinction; cloth dyed with Tyrian purple was so expensive that only priests and kings could afford it. Indigo, which for centuries was a staple dye in many eastern cultures, had been introduced by the Arabs into the Mediterranean region by the eleventh century (Cannon, Cannon, & Dalby-Quenet, 1984). During the Middle Ages (5th to 15th century), Kermes, the most commonly used red dye, was derived from dried female scaled insects. It was the principal insect dye in Europe prior to the Spanish "discovery" of the cochineal insect in the Americas (Mills & White, 1987). The Spanish conquistadors would make several trips to Mexico, returning with natural resources to trade and sell the dye to European economies. The color red was of scarce availability in Europe and the Spanish monopoly of cochineal dye would eventually become a major source of revenue.

2.1.2. Industry transition to synthetic dyes.

In the mid-19th century, a chemist named William Henry Perkin developed the first synthetic dye, "mauveine" which would impact the commercial application of natural dyes forever (Cañamares et al., 2014). This discovery provided stimulus to the British economy, and became an instrument of social, cultural and political change. Textiles became more colorful and printing became cheaper. The discovery promoted research activity of industrial manufacturing for synthetic dyes (Nagendrappa, 2010). Prior to 1920, Germany was the largest manufacturer of synthetic dyes. However, due to German embargoes placed on Allied countries during World War I, Americans saw a brief return to natural dyes. This short resurgence of natural dye usage would soon diminish, as the U.S gained access to German formulae for dyes and stains between the two World Wars (Penney, 2000). This advantage prompted a surge of new chemical and dye companies being created, thus contributing to new synthetic dye breakthrough. According to an investigation by the United States International Trade Commission (1981), in 1947, the U.S Synthetic Organic Dye (SOD) industry accounted for 65% of the world trade in SOD industry and four of the largest chemical companies were U.S. owned. The United States would remain a major player in the SOD industry until after World War II due to Europe re-establishing the manufacturing of synthetic dyes. During this time, the U.S trade of SOD's would decrease, and American chemical companies began to develop in more dynamic areas of synthetic organics, plastics, fibers, rubber, detergents and pesticides. By the 1980's, U.S SOD sales accounted for less than two percent of total synthetic organics sales. European chemical companies continued to increase their interest and leadership in SOD's through acquisition of U.S. production facilities and participation in the aforementioned new synthetic organics areas (United States International Trade Commission, 1981). According to USITC (1981), of the 20 major synthetic dye manufacturers 12 were European (including three German and two Swiss firms), five were Japanese, and three were domestically owned firms in the United States. The value of world sales in 1980 approached five billion.

2.1.3. Natural colorants- source and chemical structure.

Natural colorants are classified into various categories based on chemical structure, source of material, and application method (see Figure 1). For the purpose of this literature review, the colorant discussion will focus on chemical structure and source of natural dye for Flavonoids and Tannins, as those are the colorants typically found in the pre-consumer food waste collected for the study (Yusuf, Shabbir, & Mohammad, 2017).

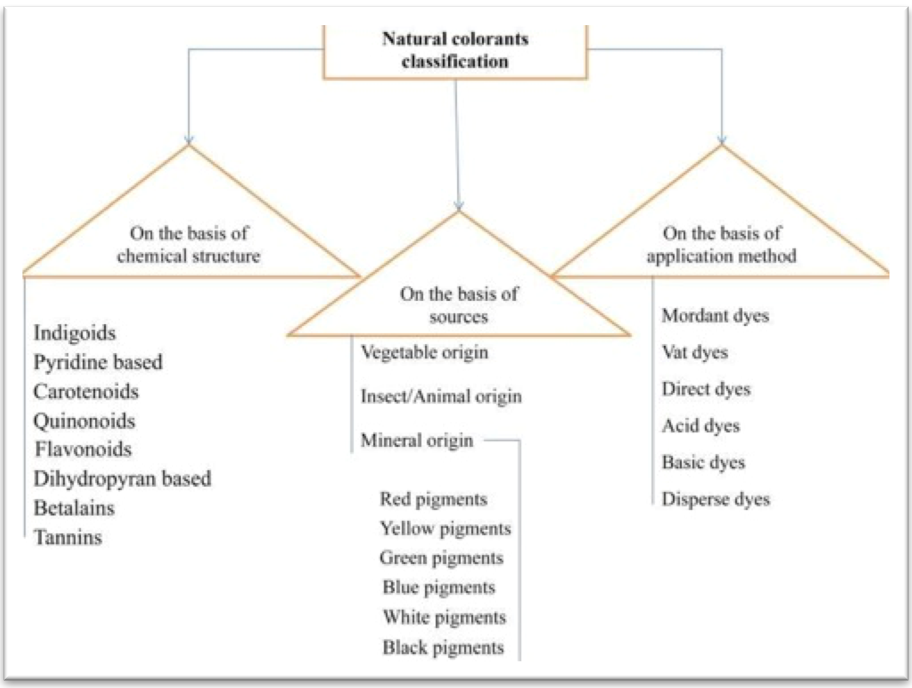

Figure 1. Classification chart for natural colorants (Yusuf, Shabbir, & Mohammad, 2017).

Natural colorants are responsible for how plants get their colors; chlorophylls, carotenoids, flavonoids and betalains are the main colorants found in nature (Griesbach, 2005). Flavonoids are the natural substances found in fruits, vegetables, grains, bark, root, stems and flowers. Due to differences in chemical structure, there are a variety of flavonoids found in plants (Panche, Diwan, & Chandra, 2016). The subgroups of flavonoids depend on the C ring on which the B ring is attached and the degree of unsaturation and oxidation of the C ring

(Figure 2). This study will focus on the subgroup made up of flavones, flavonols, flavonones, flavononols, flavonols or catechins, anthocyanins and chalcones (Panche, Diwan, & Chandra, 2016). Flavonoids contain the largest group of plant dyes with colors ranging from pale (isoflavones) to deep yellow (chalcones, flavones, flavonols), orange, red and blue (anthocyanins) (Yusuf, Shabbir, & Mohammad, 2017). Yellow onion skins, which will be collected and used for dyeing during the course of this study contain the flavonoid dye (Panche, Diwan, & Chandra, 2016).

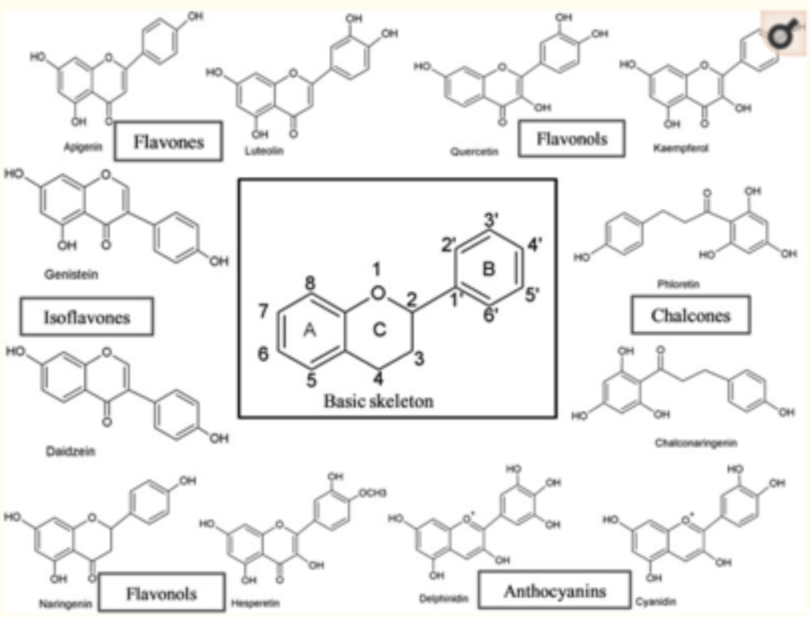

Fig. 1.

Basic skeleton structure of flavonoids and their classes.

Figure 2. Basic Skeleton of flavonoids and their classes (Panche, Diwan, & Chandra, 2016).

Tannins are complex compounds that are found in wood, bark, leaves, buds, floral parts, seeds and roots. The chemical structure of tannins is about as varied as the plant genera itself (Julkunen-Tiitto & Hggman, 2009). These compounds have many reactive sites and bond easily to other biomolecules (proteins, enzymes, carbohydrates) due to their available hydroxyl groups, making them a favored natural mordant for cellulosic and protein fibers (Julkunen-Tiitto & Hggman, 2009). Historically, tannins were used for converting raw animal hides into leather, also known as tanning, where their common place name is derived. Tannins are also used in glues, mordants, stains and inks (Yusuf, Shabbir, & Mohammad, 2017). Coffee grounds, which will be collected in this study contain the tannin colorant.

2.1.4. Handling methods for plant material.

The first step in natural dyeing is preparing the plant material (Azwanida, 2015). Preparation can include using fresh or dry materials, grinding or using powdered plant material and drying method. Below is a brief review of preparation methods:

2.1.4.1. Collection fresh vs. dried.

This is determined by how quickly the samples will be used. According to Sulaiman et al, time in between harvest and extraction should be limited to 3 hours maximum. This will help maintain freshness of the sample (Azwanida, 2015).

2.1.4.2. Drying method.

There are multiple ways to dry plant materials prior to extraction. The most common are air drying, microwave drying, oven drying and freeze drying. Air drying plant materials at ambient temperatures is the only method mentioned above that has the lowest potential to change or degrade the chemical makeup of the plant material (Azwanida, 2015).

2.1.4.3. Ground vs. powdered.

In order to increase surface contact between extracted dye and fiber, it is suggested to reduce the dye particle size. Plant material that has been ground (using mortar and pestle or blender), has a small particle size. However, powdered plant material has an even smaller dye particle size that is more homogenous, which provides better surface contact with extraction solvents and fibers (Azwanida, 2015).

2.1.5. Extraction.

Extraction refers to separating the desired color component by physical or chemical means with the aid of a solvent through defined standard procedures (Samanta & Konar, 2011). The standard method used for centuries has been cold or hot aqueous extraction using water. The process involves a technique called maceration, which involves soaking the plant material in a container for an extended period of time (Handa, Khanuja, Longo, & Rakesh, 2008). This allows the plant material to soften and deteriorate the plant's cell wall, allowing the release of colorants. The mixture is then filtered or strained to remove from larger particles (Azwanida, 2015). Infusion and decoction methods are similar to maceration; however, infusion utilizes a shorter boiling time and more precise measurement of solvent (Handa, Khanuja, Longo, & Rakesh, 2008). Generally, decoction is the method of choice for harder plant materials like bark and roots. During decoction, the plant material is macerated and boiled. This process results in oil-soluble compounds (Azwanida, 2015). More advanced extraction methods include, Ultrasound-assisted extraction (UAE), Accelerated Solvent Extraction (ASE) and Supercritical fluid extraction (SFE). During Ultrasound Assisted Extraction the plant materials cell walls are disturbed by ultrasound, thus releasing colorants and allowing the solvents to flood into the plant cells. Accelerated Solvent Extraction packs the plant sample with an inert material such as sand in a stainless-steel extraction cell. Through extreme pressure and temperature, this process eliminates long extraction times and produces a higher concentration of colorant. Supercritical Fluid Extraction is a process that uses supercritical fluids (SCF's) as the extracting solvent, usually CO_2. Diffusion is the base process behind SFE, by which the colorants on the inside of the plant material diffuse outside the cell walls and the SFC's flood in. This process is efficient but not widely used due to the initial cost of machinery and setup (Azwanida, 2015).

2.2. Cost and Benefits of natural and synthetic dye

Synthetic dyes still dominate the textile market. However, studies have shown that wastewater from textile dye houses can have an adverse effect on the surrounding environment (Yaseen & Scholz 2018). Due to the resilient nature of synthetic dyes, it is often difficult to remove them from wastewater. This can darken the surrounding water, which impacts sunlight penetration and aquatic plant growth. Fish have also been found to be contaminated through ingesting the dyes. Azo dyes represent a major classification of dyes that are used primarily on fabrics like cotton, wool and silk. Some azo dyes containing the derivative aniline have been found to be carcinogenic and can be easily absorbed into the skin (Platzek et al., 1999). Countries like Germany (Narvekar & Srivastava, 2002) and Australia (Bavas, 2014) are making strides to ban certain azo dyes from being used on textiles.

Research suggests that companies are beginning to investigate alternative sources of dyes made from renewable resources like plant material (Gilbert & Cooke, 2001). These "natural" dyes are usually agro-renewable, vegetable based and biodegradable (Samanta & Konar, 2011). In some cases, such as indigo, the plant waste produced after dye extraction becomes a good fertilizer for the agricultural industry. This reduces the need for disposal of material waste (Samanta & Konar, 2011).

Many natural dyes derived from plants, like madder, grow best in wasteland environments. Therefore, utilization of wastelands becomes added value for the natural dye industry (Samanta & Konar, 2011). Finally, colorants naturally contained in fruits and vegetables such as chlorophyll, carotenoids, anthocyanins and betanin have been found to have properties that are beneficial for humans (Rodriguez-Amaya, 2016). These natural dyes are not only used in textile dyeing, but in the food and beverage industry in addition to medicine. The literature summarizes the health benefits as follows: antioxidant (Panche, Diwan, & Chandra, 2016), anti-bacterial (Sathianarayanan, Bhat, Kokate, & Walunj, 2010), antimicrobial (Singh, Jain, Panwar, Gupta, & Khare, 2005), anti-inflammatory, anti-fungal and UV- protective (Sarkar, 2007).

2.3. Summary

Natural dyes can be traced back to the beginning of human civilization, when they were used to draw and communicate with images on cave walls; decorate the bodies of warriors and adorn the clothing of royal and religious leaders. As science and technology advanced, natural dyes began to disappear. Furthermore, the chemical structure of natural dyes resulting in adhesion limitations such as poor wash and light fastness, and limited color range, allowed synthetic dyes to supersede in the growing global economy. Even though synthetic dyes are the currently preferred choice of most textile dye houses, studies have shown that some synthetic categories such as azo dyes include colorants that are harmful to the environment as well as toxic to the people who come in contact with them. There is a current push in research to investigate ways to improve natural dyes' limitations and improve the helpful qualities such as antioxidant and UV protection. Ongoing research provides more insight into the potential uses for natural colorants. However, due to their poor colorfastness, improvements must be made to increase large scale production and commercial viability (Shahid, Shahid-Ul-Islam, & Mohammad, 2013).

2.4. Natural Mordants

This section of the literature review will examine common mordants used in the natural dye industry, three common processes for mordanting textile fibers, and the necessity of mordanting natural fibers.

2.4.1. Common mordants used.

Many natural dyes stain fibers, however, without the presence of a mordant the colorfastness is very low and shade range is limited. A mordant is a substance that acts as a chemical link between the fiber and natural dye, allowing the dye to bond and become fixed to the fibers (Dean, 2010). Figure 3, illustrates how a metal mordant (Mn+) acts as a chemical link between the polymer chain of textile fibers (cellulose) and natural dye alizarin (Madder). Research shows that mordants influence physical properties including colorfastness, brightness of dye, and fastness to rubbing (Montazer, Parvinzadeh, & Kiumarsi, 2004). Depending on the choice of mordant, it has the potential to change the hue of the color by brightening or darkening the dye (Yi & Cho, 2008). This is heavily dependent on chemical makeup of mordants, fibers and metal ion relationship between fiber and dye (Tang et al., 2010).

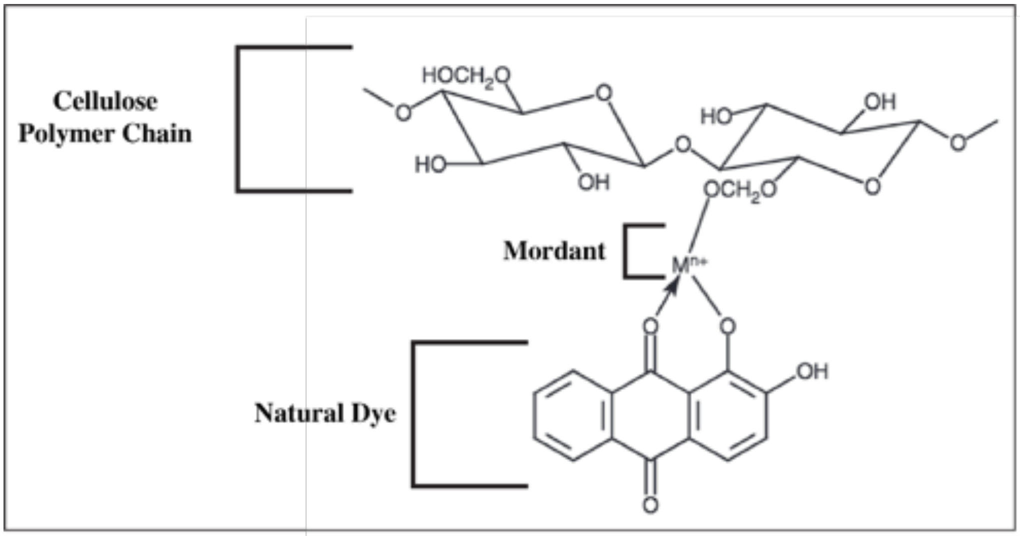

Figure 3. Bonding of a natural dye to cellulose by means of a mordant (M^{n+}) as illustrated with alizarin (Ding & Freeman, 2017).

Most mordants used prior to the 19th century were metals such as Cu^{2+} and Cr^{6+} (Sugar & Meyers 2002; Vankar, 2007). However, common current mordants are, aluminum potassium sulphate, stannous chloride, ferrous sulphate and copper sulphate (Samanta & Agarwal, 2009). Unfortunately, an adverse environmental issue in natural dyeing is the amount wastewater generated. The wastewater can contaminate surrounding bodies of water if not disposed of properly. Due to recent efforts in sustainability, more eco-friendly alternatives like using rare earth chlorides have been developed in order to limit the amount of metal ion exhaust that is put into wastewater following the completion of the dye process. (Zheng et al. 2011). For the purpose of this study, Aluminum Sulfate $Al_2(SO4)_3$, was the mordanting agent . Aluminum Sulfate is one of the safest metallic salts to use for the mordant process, when used at the correct proportions of fabric weight (Savvidis et al., 2013; Zarkogianni et al., 2010).

2.4.2. Overview of mordant process.

The mordant process can be completed in three different stages of the dyeing process, Pre, meta and post-mordant (Figure 4). The literature discusses advantages and disadvantages of mordant application at all stages. Pre- mordant process occurs prior to textile fibers being introduced to natural dye. This is the first step in the dyeing process, allowing the mordant sufficient time to interact with available sites on the fiber. This step is important to develop optimum utilization of mordant, so the mordant content in the wastewater is not high, minimizing effects on plant and animal life (Yusuf, Shabbir & Mohammad, 2017).

The meta/simultaneous mordant process occurs when both mordant and dye are introduced to the fiber at the same time. One advantage of this process is that energy is not used to heat separate mordant and dye baths because only one bath is used. However, this process causes higher waste of both mordant and dye. In the presence of each other, the dye and mordant will sometimes bind but not on the fiber. This causes lower mordant and dye adherence to fiber which causes uneven dyeing (Yusuf, Shabbir, & Mohammad, 2017). During the post-mordant method, the textile fiber is treated with the dye, then to the mordant. This method is mainly used to help brighten and broaden the depth of shade by combining dye and mordant particles on the surface of the fiber. (Yusuf, Shabbir, & Mohammad, 2017).

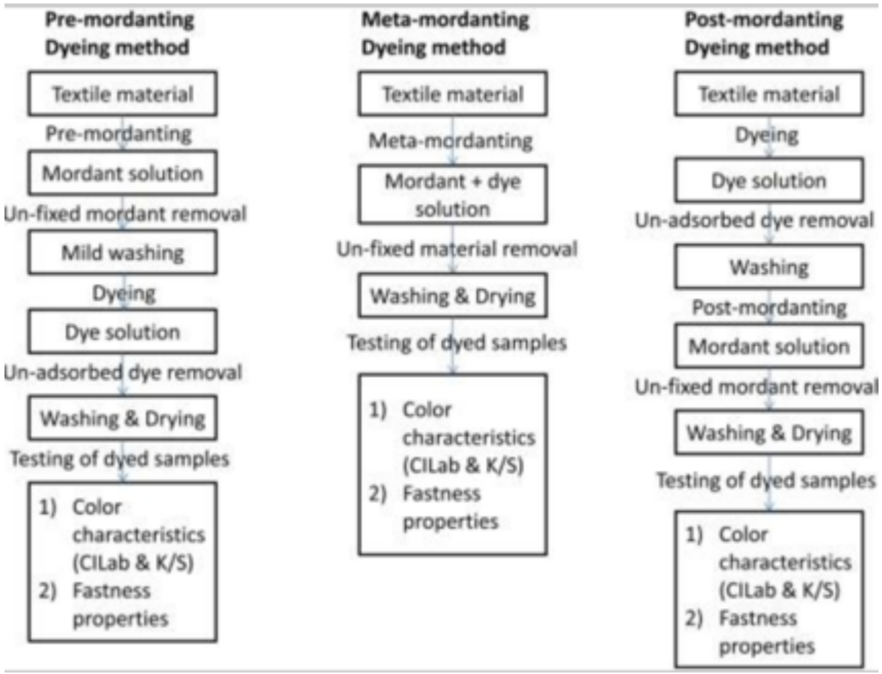

***Figure 4*.** Flow chart for dyeing methods with different mordanting techniques (Yusuf, Shabbir, & Mohammad, 2017).

2.4.3. Summary.

Mordanting is an important step in the natural dye process. The chemical bond between the mordant, fiber being dyed, and natural colorant becomes stronger, which contributes to better textile fastness properties. Mordanting can be done in three stages, with each stage having advantages and disadvantages. Choosing the correct mordant for natural colorants and textile is important to the dye process. While some mordants are more environmentally friendly, metal mordants do have negative aspects such as water contamination if excessive exhaust is left in the wastewater. Being able to improve natural dye color fastness in addition to a mordant that is not harmful to the environment has the potential to increase natural dye utilization.

2.5. Human perception of Color

This section of the literature review will discuss color theory and what factors can influence how color is perceived.

Color is experienced by human beings' due to an interaction of light and objects with our eyes and brain (Kuehni, 2013). For example, an object absorbs light and it reflects visible wavelengths that our brain then translates into color (Keiser, Vandermar, & Garner, 2017). For humans to view color, the light an object reflects has to be within specific wavelength range (400 to 700 nm). Reflectance of lower, shorter wavelengths (400 nm) produce a violet color while higher, longer wavelengths (700 nm) produce red. (Figure 5).

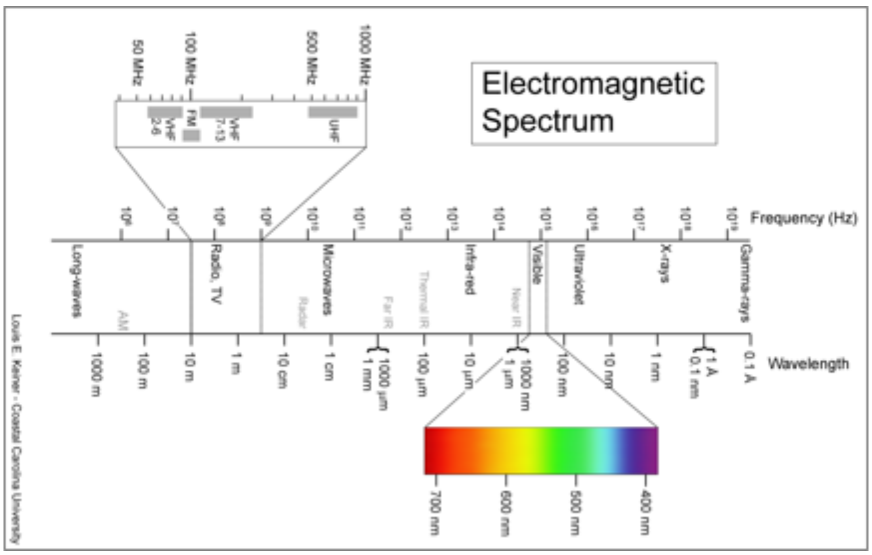

Figure 5. The Electromagnetic Spectrum (Reprinted from Louis E. Keiner, Coastal Carolina University

External factors such as light source, color memory, age, and surrounding colors have the ability to alter one's perception of color. Hinks and Shamey (2011) found that spectral power distribution (SPD) of the light source is the fundamental factor that defines the way color is perceived. Standard light sources include natural daylight, incandescent and fluorescent. When placed in a retail store, each type of light has the potential to impact how consumers perceive the color of a product, which may be different than originally intended by the designer (Hinks & Shamey, 2011). Light plays an important role in human color perception and is a deciding factor in how it is perceived.

2.6. Food Waste in Landfills

This section of the literature review will discuss the environmental impact of food waste and alternative ways of diverting food waste from landfills.

2.6.1. Recycling industrial waste.

Efforts from industries to be more environmentally conscious are becoming apparent as positions like Chief Sustainability Officer are more commonplace. Industries are taking into account how their processes of waste management and disposal impact the people and planet sections of the company's bottom line. A novel way of looking at the issue of waste would be to understand how waste is utilized in nature. Many analogies between the industrial system and ecology have been made; for example, animals ingest and digest food and produce waste. Similarly, industries use resources, process them and produce waste. Ayres (2004) refutes this idea by stating exchanges in nature are involuntary unlike exchanges in economics that are based in a system of value. However, the natural dye industry's use of cheap by-products from agriculture, forestry and food processing make it the perfect waste recycling industry. As illustrated in Figure 6, forestry cast offs such as ash tree bark, and leaves are all products that can be used in natural dyes (Bechtold, Mahmud-Ali, & Mussak, 2007).

The food and beverage industry produces large amounts of colored vegetable waste like pressed berries (Bechtold et al., 2006), pomegranate rind (Sinha, Saha, & Datta, 2012), and other products containing colorants that are sources of natural dyes. Utilizing other industries' waste products is a sustainable strategy for the natural dye industry. Although there are many positives regarding recycling of industrial waste, large scale extraction of natural dyes from plant material utilizes large amounts of plants, which also yields a large amount of waste. As seen in Figure 6, this study will integrate a recycling system of utilizing pre-consumer food waste as a natural dye; dyeing a tote bag and recycling the viable waste at a compost facility.

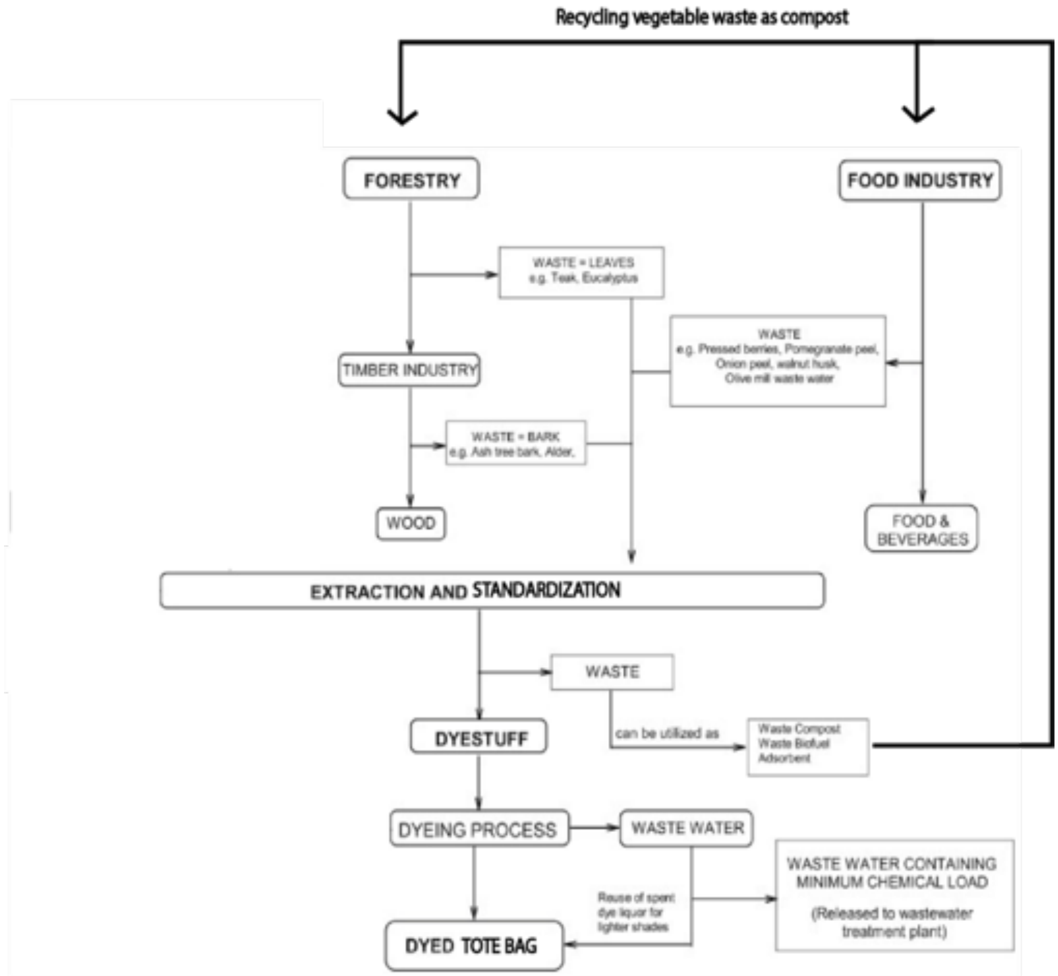

Figure 6. A schematic representation of enhanced resource utilization and waste minimization in a natural textile dyeing (Shahid, Shahid-Ul-Islam, & Mohammad 2013).

2.6.2. Environmental impact of food waste in landfills.

In 2010, three percent of the 31 million tons of post-consumer food waste was recycled in the United States. Food waste was the largest category of municipal solid waste that reached landfills (United States Environmental Protection Agency, 2011). In 2009, researchers studied the environmental impact of food waste and determined resources like water, land and fuel necessary to grow and transport food were wasted when edible food was thrown away (Hall et al., 2009). Food waste contributes to excess methane, CO_2 and other greenhouse gas emissions from decomposing food which impact global climate change (Hall et al., 2009). Allowing food to rot in a landfill creates methane gas, which is 28 to 36 times more effective than carbon dioxide at trapping heat in the atmosphere, which contributes to global warming. (Basic Information about Landfill Gas, 2019). Municipal solid waste (MSW) landfills are the third largest source of human generated methane emissions. MSW released an estimated 27.5 million metric tons of carbon in 2009 (Basic Information about Landfill Gas, 2019). Diverting food waste from landfills, will reduce the amount of greenhouse gases and has the potential to create renewable sources of energy as fertilizer. A common food waste diversion practice is composting, which will be discussed in the next section of the literature review.

2.6.3. Composting.

Composting municipal solid wastes is a beneficial alternative to the landfill or incinerators (Saer, Lansing, Davitt, & Graves, 2013). Unfortunately, only 0.85 million tons of the 20.8 million tons are actually composted (Municipal Solid Waste (MSW) in the United States: Facts and Figures, 2010). During the composting process, food waste is decomposed by microorganisms under low pressure, aerobic conditions. This series of events results in nutrient rich fertilizer that can replace current harmful fertilizers (Levis, Barlaz, Themelis, & Ulloa, 2010). However, composting also has negative effects on the environment such as, CO_2 emissions from fossil fuel use in transportation and processing equipment, odors from composting process, and methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3) emissions from anaerobic conditions during the composting process (Amlinger et al., 2008; Boldrin et al., 2009; Edwards & Williams, 2011). Considering the tradeoffs, composting provides an alternative for food waste that contributes to environmental benefits such as improving soil quality, reducing the need for pesticides, increasing water retention and erosion and increasing carbon storage in soil (Favoino & Hogg, 2008; Martínez-Blanco et al., 2013). Composting can provide a closed loop type of recycling system for the food industry. As the pre-consumer food waste is discarded during kitchen preparation, it can be composted and utilized by the farms producing the fruits and vegetables that are consumed the food industry.

2.6.4. Summary.

Industrial systems are similar to ecosystems in nature, as resources are utilized waste is produced. Many industries are re-examining their environmental impact, and recycling waste such as leaves, bark, and plant food waste. Developing solutions for issues such as food waste is an important factor in reducing greenhouse gases, which negatively impacts the global climate. A solution discussed included composting, which is a beneficial alternative to burning trash and reusing waste. Composting has the ability to create a continuous recycling system as food waste is broken down into fertilizer that grows the food needed to sustain life.

2.7. Consumer Behavior Theory

This section of the literature review will the history of consumer acceptance of sustainable products and what factors have influenced change in this niche sector. Additionally, consumer behavior theories pertinent to this study will be presented. Desire for Unique Consumer Products and Theory of Planned Behavior are explored as predictive factors for a textile product.

2.7.1. Consumer acceptance of sustainable textile products.

The last three decades have seen a major shift in public opinion regarding sustainability. Concerns over limited resources, and potential climate risks caused by human behavior are significant concerns for society. (United Nations World Summit on Sustainable Development, 2002). Sustainability initiatives are now integrated into the economic, social and business aspects of cultures. Eifler and Diekamp (2013) summarize three cycles which eco-friendly textile products have experienced in the 20th century. The discussion of consumer acceptance of environmentally friendly products began in the late 1960's when new social movements and political activism were prevalent in the United States. During this time, clothing was a tool for activism and refusal of societal norms. Environmental clothing took on a distinct look, as naturalness and rejection of consumerism were important themes. In the apparel industry, the "eco-frumpy" look was characterized by "long cotton dresses, baggy home-made, woolen pullovers, sandals, flapping trousers and overalls made from unrefined natural materials" (Eifler & Diekamp, 2013). Natural dye use was commonplace during this time, as it symbolized the rejection of synthetically treated textile products.

The 1980's was a time of global conversation and policy remediation regarding depleting resources, impending climate change and generational education to reduce, reuse, and recycle. During this time apparel designers and producers using natural dye struggled to incorporate colors and silhouettes that were desirable and aesthetically pleasing to a larger audience.

The 2000's also saw a surge of consumer demand for more sustainable textile products. The textile industry intersects across many waste creating sectors, and consumers were demanding a change. In 2013, a study conducted in Germany exploring perception of sustainable clothing found that participants are aware of sustainable clothing. However, barriers such as limited number of stylish offers, poorly defined retail outlets, lack of transparency in textile ecological developments and an assortment of pricing issues keep consumers from making it a purchasing factor (Eifler & Diekamp, 2013). A mixed methods study (n = 50) was conducted at the University of Maryland in which participants were interviewed and surveyed about their acceptance of the locally produced eco-textiles. The survey concluded that most participants were willing to purchase and pay a premium price for the textile. However, factors such as lacking 'private' good quality (health, taste, freshness) (Wier, O'Doherty et al., 2008), accessibility, and labeling may prevent participants from purchasing locally made sustainable textile products (Cao et al., 2014). Research shows consumers are interested and willing to purchase sustainable textile products, but certain factors might outweigh the value that product may provide.

2.7.2. Desire for unique consumer products.

From a marketing perspective, uniqueness has been defined as, "products that are highly differentiated from other products in their category on the basis of perceivable sensory, image, functional, emotional or other product characteristics that are positively valued by the consumer" (Cardello et al., 2016, p. 24). This feature adds perceived value to the consumer because it is seen as "one of a kind" (Carpenter, Glazer, & Nakamoto, 1994). This perceived value helps consumers develop a distinct self-image (Tian et al., 2001).

Another way consumers may establish a self-image is through dissimilarity through products and purchasing avenues. This may include purchasing/displaying novelty, vintage, antique, personalized, or handcrafted goods, as well as purchasing in nontraditional outlets such as antique stores, garage sales, and swap meets (Tepper, 1996). The Need for Uniqueness theory (NFU) addressed people's perceptions of their similarity to others and their reactions to such perceptions (Snyder & Fromkin, 1977, 1980), and measures how much a person tries to be similar or dissimilar to people around them. For example, a person with a high need for uniqueness desires to be very different than the people around them. The NFU is measured across three aspects. First, creative choice counter conformity, which is a person's ability to use products to create a self-expression (Lynn & Harris, 1997). The second aspect is unpopular choice counter conformity which uses products to deviate from social norms that have the potential to enhance social image (Tian et al., 2001). Lastly, avoidance of similarity, in which effort to avoid using widely adopted products is utilized. These consumers try and avoid using or buying products once they become mainstream (Thompson & Haytko, 1997).

The Desire for Unique Consumer Products scale (DUCP) is an assessment that measures how uniqueness motivation influences consumer behavior. The assessment uses similar dimensional aspects of NFU and is positively associated with scores on the measures of general innovativeness and of domain-specific innovativeness for fashionable clothing (Goldsmith, Clark, & Goldsmith, 2014). A higher level of DUCP tends to correlate greater acceptance of a unique or customized product (Jin & Son, 2014). This study will use a Desire for Unique Consumer Products scale, which has been modified from the original Need for Uniqueness Scale, to assess the impact of product choice.

2.7.3. Theory of planned behavior - sustainability.

The framework precursor to the Theory of Planned Behavior (TPB) was based on the concepts explained in Theory of Propositional Control (TPC) by Donelson E. Dulany, in which the relationships among attitude, behavior and other variables were analyzed (Ryan et al., 1975). The theory explains that a certain behavior is not necessarily improved by the incentive of a reward or discouraged by punishment, but that people form a behavioral intention to act a certain way (Ajzen, 2012; Dulany, 1965). Dulany suggested that behavioral intention toward an action is determined by the following characteristics; motivation to comply with what they believe is a desired action (attitude), what they feel is expected of them and "what they think they are supposed to do" (subjective norms) (Dulany, 1965). Attitude and subjective norms are factors for determining intention. Both attitude and subjective norms are belief systems that are ingrained in people. Attitude is a personal belief system and subjective norms takes into account "other people's opinions of self" (Salazar, Oerlemans, & van Stroe-Biezen, 2013). The Theory of Planned Behavior expanded TPC by including perceived behavior control, which is a reflection of people's confidence in their ability to perform a certain action, in addition to rating a person's resources and opportunities to carry out a behavior (Ajzen & Madden, 1986). Theory of Planned Behavior (TPB) states that attitude toward a behavior, subjective norms, and perceived behavioral control (PBC), together shape an individual's behavioral intentions, which in turn reflects how an individual is motivated to perform the behavior (see Figure 7) (Thoradeniya, Lee, Tan & Ferreira, 2015).

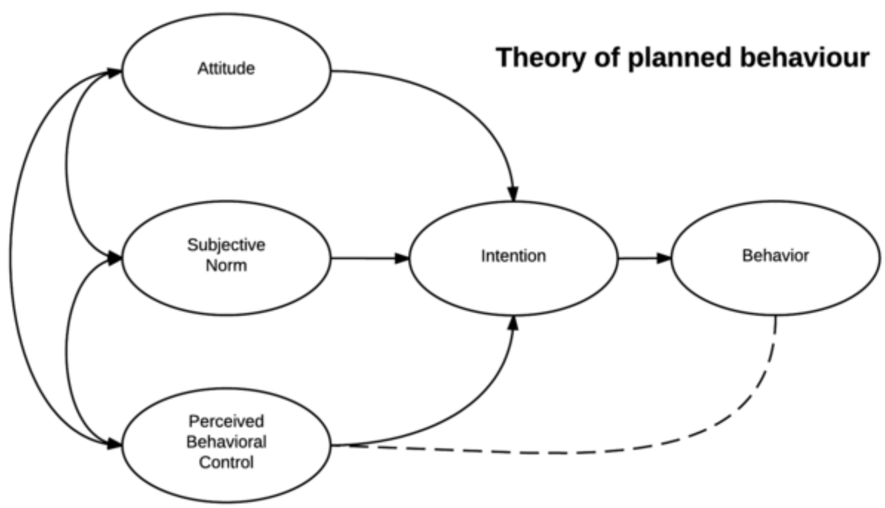

Figure 7. The Theory of Planned Behavior (Azjen & Madden, 1986).

Researchers Jin and Ko (2017) utilized TPB to predict U.S and Chinese consumer purchase intentions toward green apparel products. Results indicated that as environmental knowledge increases, consumers displayed a greater attitude toward a green apparel purchase. Of the U.S participants, subjective norm, internal PBC, respectively influence purchase intention the most, while attitude influenced the least. When compared with Chinese participants, subjective norm and external PBC, respectively influence purchase intention the most, and internal PBC the least.

The theory of planned behavior has been proven to be superior in explaining behaviors that are within one's control (Ajzen, 1991). As a result, this study will analyze planned behavior toward the environment, in which positive attitudes are associated with high environmental preservation, and subjective norms and perceived behavior control are applied to environmental beliefs (Mancha et al., 2014). The research conducted and results provided will help better understand consumer behavior toward sustainably produced textile products.

2.7.4. Summary.

Public opinion toward sustainable products has gone through many changes due to political, economic and environmental influences. Research has shown that consumers are aware of sustainable products, but barriers such as price, transparency, lack of diverse silhouettes and purchasing avenues prevents them from making the sustainable option a purchasing factor (Eifler & Diekamp, 2013). Understanding how consumers develop purchase intentions is key for product development and marketing. Desire for uniqueness and planned behavior toward sustainability are theories explored in this research in order to determine if they are predictors of textile product choice. Uniqueness motivation has the potential to impact purchasing avenues, products consumed, and styles adopted. The DUCP scale used in the study attempted to assess how this desire influences behavior. Similarly, the Theory of Planned Behavior toward Sustainability examines how intention to act a certain way is determined by attitude, subjective norms, perceived behavioral control, which in turn determine the behavior. These behavior theories have the potential to help textile and companies better understand their consumers and develop products that tap into their purchasing intentions.

CHAPTER 3
METHODOLOGY

3.1. Research Design

The purpose of this research was to learn about the natural dye process and consumer acceptance of a natural dye containing textile product. In order to do this, a two-step process was applied:

1. Using restaurant pre-consumer food waste, natural dyes were extracted, and a consumer product was dyed and evaluated against a synthetic dye containing product.
2. Consumer acceptance of the product was assessed using the Theory of Planned Behavior and Desire for Unique Consumer Products.

3.2. Research Hypotheses

The study utilized a null hypothesis where participants' desire for unique products and level of planned sustainable behavior will have no effect on which dyed textile product (tote bag) they rated more highly.

Experimental Treatments:

Treatment 1: Participants were not subject to an explanation of dye process for textile products

Treatment 2: Participants were subject to an explanation of dye process for textile products

Hypotheses:

H_{01}: Level of Desire for Unique Consumer Products will have no effect on the choice of bag during treatment 1 and 2.

Independent Variable: Level of Desire for Unique Consumer Products

Dependent Variable: Bag Choice

H_{02}: Level of Planned Sustainable Behavior will have no effect on the choice of bag during treatment 1 and 2.

Independent Variable: Level of Planned Sustainable Behavior

Dependent Variable: Bag Choice

H_{03}: Treatment 2 will have no effect on how participants' respond to the color to the bags during treatment 1 and 2.

Independent: Treatment 2

Dependent Variable: Color response to bag

H_{04}: Treatment 2 will have no effect on how participants' respond to the visual appearance of the bags during treatment 1 and 2.

Independent: Treatment 2

Dependent Variable: Visual Appeal response to bag

3.3. Phase One

Using restaurant pre-consumer food waste, natural dyes were extracted, and a consumer product was dyed and evaluated against a synthetic dye comparison.

3.3.1. Plant material selection and collection.

The pre-consumer food waste materials in this study were used coffee grounds and yellow onion skins (Figure 8 and 9). The selection of these materials was based on consistent availability, sufficient quantity, and willingness of kitchen staff to separate waste while not impacting workflow. The used coffee grounds (*Coffea arabica L.*) and yellow onion skins (*Allium cepa L,*) were collected every two weeks from North Carolina State University main campus eateries such as Starbucks and Clark Dining Hall. The yellow onion skins were also collected from AC Restaurants in Raleigh, North Carolina. Both items were stored in a plastic container and placed in a refrigerator of a constant 35° F (1.6° C) temperature until time of extraction.

Figure 8. Used coffee grounds.

Figure 9. Yellow onion skin, (Shutterstock; Web, 22 April 2019).

3.3.2. Fabric and accessory selection.

Fabric selection was based on optimal adhesion with natural dyes (natural fibers). The fabric selected for this study was commercially produced 100% cotton duck canvas bleached (7.0 oz.) made of single fill plain weave. The fabric was purchased from Big Duck Canvas Company. The tote bag handles were 100% natural cotton webbing measuring 1.5 inches in width. Cotton webbing was purchased from an online Amazon vendor, QIANF - High Grade Webbings. The tote bags were sewn using 100% mercerized cotton thread from Coats and Clark.

3.3.3. Mordant selection.

For the purpose of this study, the mordant chosen was aluminum sulfate $Al_2(SO_4)_3$, because it is one of the safest metallic salts to use for the mordant process (Savvidis et al., 2013; Zarkogianni et al., 2010). The aluminum sulfate was purchased from Nuts.com. The pre-mordant process was selected to allow sufficient saturation time of the mordant with the fiber sites, and consequently less mordant effluent is left in mordant bath. The mordanting process was carried out in the Pilot Laboratory located in the Wilson College of Textiles.

3.3.4. Mordanting procedure.

Fabric was cut into 6 x 6 inch samples (n =12) that weighed 4.0 g each. The total amount of mordant was weighed out (4.8g), which was based on 10% (w/w) (Sarkar & Seal, 2003). The mordant was mixed with 100mL of water at 71°C until dissolved. The solution was added to 5L of cold water in a 12 quart stainless steel pot and stirred. The fabric samples were previously wetted using the Mathis HVF machine. The machine was set to the horizontal position with 250mL of tap water added to the basin. The machine was set to a pressure of 2 bars and speed of 1.0 m/min. Wetted fabric samples were added to the mordant solution, and sufficient water to enable fabrics to move freely. The stainless steel pot containing the fabric, was placed in a larger kettle filled with water (using double barrel boil method, see figure. 10) and heated to 82°C and held for one hour. The fabrics were left to cool in mordant bath overnight and removed and rinsed the next day.

Figure 10. Illustration of double barrel method.

3.3.5. Extraction and application procedure.

This study utilized the hot aqueous extraction method for extracting dye without drying or grinding of the plant material. This extraction method was the optimal choice due to project funding and available machinery. This method will maintain the integrity of the plant material to use as compost following colorant extraction. To reduce energy used during the study, the extraction and dyeing process occurred simultaneously.

Tap water (1000mL) was boiled (100°C) using the double barrel boil method (Figure 10) and 10g of plant material was placed in hot water for 10 minutes to create the dye solution. The solution was cooled to 60°C and the previously mordanted fabric was wetted and added to the dye solution for 15 minutes. The fabric along with dye solution was placed in a plastic bag and allowed to stand overnight to achieve a darker shade of color. After 24 hours, the fabric was washed with a pH neutral soap, rinsed thoroughly and air dried. The steps were repeated using 20g and 40g of plant material. Then, a second set of experiments were conducted using 500mL of tap water to test if the change in liquor to material ratio (1:250 to 1:125) would produce a deeper shade. See Table 1for a list of the dye trials performed and Figures 11-22 for dyed sample images. The pictured samples below are completely dry.

Table 1. Dye Application Trials.

Sample	Plant Material	Mordant (g)	Weight of Plant Material (g)	Water (mL)
K- 001	Onion Skins	0.4	10	1000
K- 002	Onion Skins	0.4	20	1000
K- 003	Onion Skins	0.4	40	1000
K- 004	Coffee Grounds	0.4	10	1000
K- 005	Coffee Grounds	0.4	20	1000
K- 006	Coffee Grounds	0.4	40	1000
5- 001	Onion Skins	0.4	10	500
5- 002	Onion Skins	0.4	20	500
5- 003	Onion Skins	0.4	40	500
5- 004	Coffee Grounds	0.4	10	500
5- 005	Coffee Grounds	0.4	20	500
5- 006	Coffee Grounds	0.4	40	500

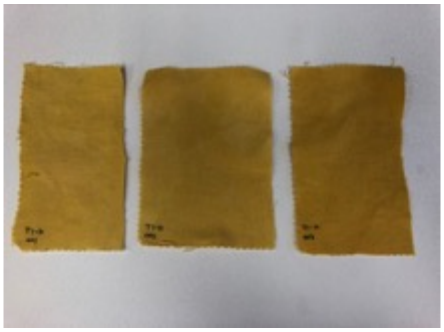

Figure 11. Trial 1 K001-003 Samples.

Figure 12. Trial 2 K001-003Samples.

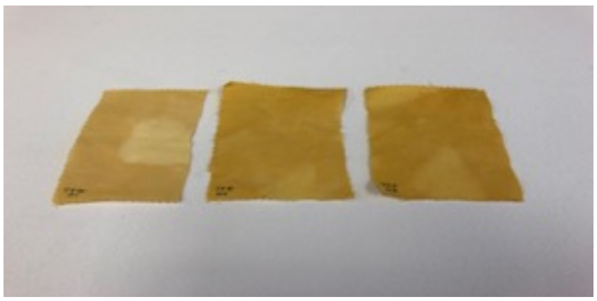

***Figure 13*.** Trial 3 K001-003 Samples.

Figure 14. Trial 1 K004-006 Samples.

Figure 15. Trial 2 K004-006 Samples.

Figure 16. Trial 3 K004-006 Samples.

Figure 17. Trial 1 5001-003 Samples.

Figure 18. Trial 2 5001-003 Samples.

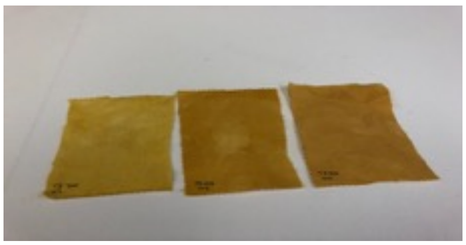

Figure 19. Trial 3 5001-003 Samples.

Figure 20. Trial 1 5004-006 Samples.

Figure 21. Trial 2 5004-006 Samples.

Figure 22. Trial 3 5004-006 Samples.

3.3.6. Sample testing setting.

Standard AATCC test methods were conducted in the Physical Testing and Pilot Laboratory located in the Wilson College of Textiles.

3.3.7. Colorfastness testing procedure.

The following standard AATCC test methods were performed:

1. Colorfastness to Crocking - AATCC Test Method 8
2. Color Fastness to Laundering: Accelerated- 61

3.3.7.1. AATCC test method 8 – colorfastness to crocking.

This test was selected to evaluate the colorfastness properties of the dyed samples. The purpose of this test is to measure the color transfer of the dyed textile surface to other surfaces with rubbing. This standard test method evaluates color transfer to both dry and wet white test cloths. The crockmeter is the instrument used to simulate the continuous rubbing of a human finger or forearm (Figure 23). Color transference from the test specimen to the white test cloth was evaluated by using the AATCC Evaluation Procedure 2 Gray Scale for Staining (American Association of Textile Chemist and Colorists, 2019).

Figure 23. Crockmeter Instrument (Amazon, n.d).

3.3.7.2. Colorfastness to crocking procedure.

Prior to testing, the dyed fabric samples were cut on the oblique in 20 x 130 mm (Figure 24). During this test, dyed fabric samples were conditioned at least 24 hours at 21 ± 2ºC (70 ±4ºF) and 65 ± 5% relative humidity. The white woven crock test cloth was mounted onto the peg, and the dyed specimen on the crockmeter base. The crock arm was lowered on the specimen and the crank handle was turned 10 times to simulate a rubbing movement. The crock square cloth was removed and left to condition for 24 hours prior to color transfer evaluation. For the wet crock sample, wet pick up to 65% $\pm$ 5% of the sample weight was established on crock square. The same procedures above were followed for the wet crock sample.

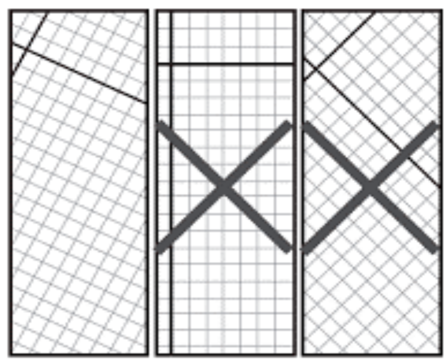

Figure 24. Oblique alignment of specimen (left) (AATCC, 2007).

3.3.8. Evaluation of color staining.

AATCC Evaluation Procedure 2 Gray Scale for Evaluating Staining was used to evaluate and quantify the color transfer as a result of rubbing from colorfastness tests. The instrument, Gray Scale for Evaluating Staining consists of nine pairs of grey and white chips from grades 1 to 5 (with four half steps) (AATCC, 2007) (Figure 25). The grades include a 5-1 range, 5 indicating no color transfer to 1 representing the most color was transferred (Table 2). Evaluated samples were placed in a light box under viewing conditions that included illumination level of daylight on a gray background at 45 ± 5° incident light and viewing direction of 90 ± 5° to the surface plane. A gray mask was placed over each sample during evaluation to eliminate the influence of surrounding areas.

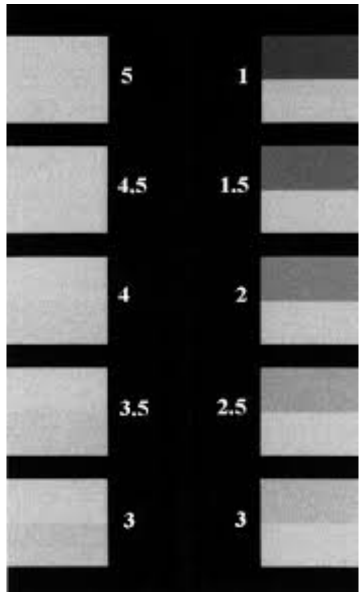

Figure 25. Gray scale for Evaluating Staining (AATCC, 2010).

Table 2. Gray Scale Rating.

Grade	Description
5	Equal
4.5-5	Slight
4	Slight
3- 4	Noticeable
3	Noticeable
2 -3	Considerable
2.0	Considerable
1-2	Much
1	Much

3.3.9. AATCC colorfastness to accelerated laundering 61-2013.

This test was selected to evaluate the color properties of textiles that would be laundered often. The dyed fabrics were tested for colorfastness to Accelerated Launderings according to AATCC Test Method 61 (AATCC, 2010). Factors such as detergent, low temperature, abrasion from canister and steel balls and low liquor ratio were factors that possibly contributed to color loss. The machine used during this test was the Atlas Launder-Ometer located in the Pilot Laboratory in Wilson College of Textiles (Figure 26).

Figure 26. Atlas Launder-Ometer.

3.3.9.1. Colorfastness for accelerated laundering procedure.

Dyed samples were cut into 50 x 150 mm (2.0 x 6.0 in) strips and stapled to the 8 mm multi-fiber test fabrics. Test 2A was used to replicate 5 home launderings (Table 3). The detergent solution made up of 1993 AATCC Standard Reference Powder Detergent and water were equally distributed in each Type 2 stainless steel canister, followed by each test specimen and appropriate number of stainless steel balls. Lids were then sealed and the Type 2 canisters were loaded horizontally into the machine shaft to run for 45 min. After completion, the canisters were emptied into a beaker and test specimens were rinsed 3 times at 40 ± 3°C for 1 minute periods. Test specimen were blotted dry and placed in an air circulating oven at 71°C. After drying, the test specimens were conditioned at 65 ± 5% relative humidity and 21 ± 2°C for 1 hour before evaluating.

Table 3. Test Conditions for Washfastness.

Test No.	Temp.	Total Liquor Volume (mL)	Powder Deterg. of Total Volume	% Chlorine	No. of Steel Balls	No. Rubber Balls	Time (min)	Test Correlation
2A	49°C 120°F	150 mL	0.15	None	50	0	45min	5 home machine launderings @ 38± 3°C (100±5°F)

3.3.9.2. Evaluation of color change.

The AATCC Test for Colorfastness to Laundering: Accelerated was evaluated using the Gray Scale for Evaluating Color Change. This scale quantifies and grades color loss from a dyed specimen. The change in color scale is made up of nine pairs of grey chips, from grades 1 to 5 (with four half steps). Grade 5 represents no change and grade 1 depicts severe change in some standards. (Figure 27). Evaluated samples were placed in a light box under viewing conditions that included illumination level of daylight on a gray background at 45 ± 5° incident light and viewing direction of 90 ± 5° to the surface plane. The material exhibiting the transferred color is placed behind the scale, so the representative part of the test sample is visible through a circular hole on the scale (AATCC, 2010).

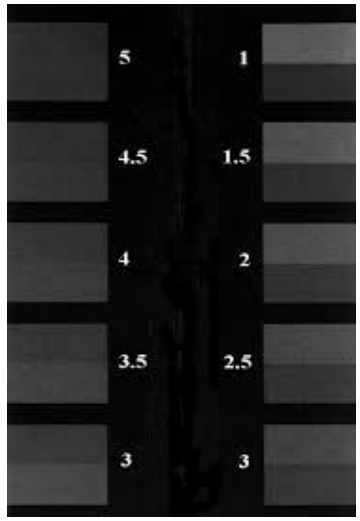

Figure 27. Gray Scale for Evaluating Change in Color (AATCC, 2010).

3.4. Color Evaluation

The purpose of the color evaluation test is to evaluate the L*a*b* values of the dyed samples. L* represent the lightness value where L = 0 is black and L = 100 is white. The a* value is the green-red component and the b value is the blue -yellow component (Figure 28). The machine and software used for this test were the Color i7 Benchtop Spectrophotometer and Color iControl. In order to calibrate the spectrophotometer, information such as sample port size, type of illumination (D65-10), reflectance or transmittance data are necessary. Calibration is an important step when using the spectrophotometer and should be performed every eight hours, or after the mode has been changed.

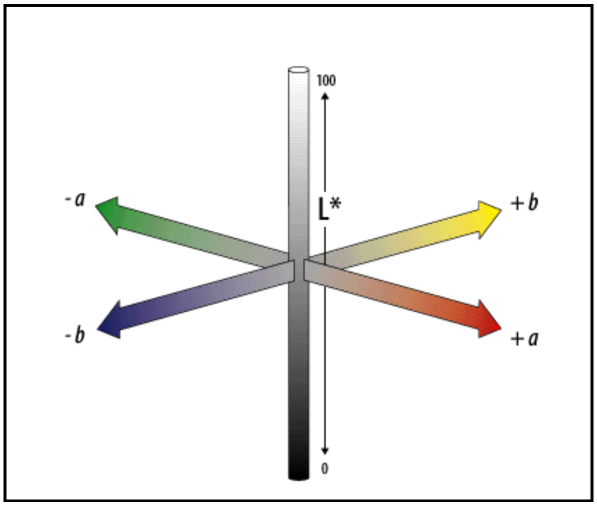

Figure 28. L*a*b* color Axis.

3.4.1. Color evaluation procedure.

The spectrophotometer was calibrated by selecting a specific illumination mode and placing a white and black tile on the instrument port to standardize the sensor. The dyed samples were folded twice and placed in the viewport. Reflectance measurements and L*a*b values are collected and recorded. This step is repeated three times with measurements averaged. The original 100% bleached cotton sample is used as the measurement standard which the dyed samples (trials) are compared.

3.5. Phase Two

Consumer acceptance of the product was tested using the Theory of Planned Behavior and Desire for Unique Consumer Products.

3.5.1. Textile product selection.

This study utilized a tote bag as the textile product for participants to evaluate. This item was chosen due to its basic products characteristics.

3.5.2. Textile product development setting.

The tote bags were sewn in the Apparel Laboratory and dyed in the Pilot Laboratory located in the Wilson College of Textiles.

3.5.3. Procedure - tote bag development.

The tote bag was 19.25 x 14.5 inches long, with finished dimensions of 15.5 x 14 inches (Figure 29). The tote bag was cut with the bottom on fold, and side seams were sewn using a 504 Overlock and 301 Lockstitch machines. Two 25 -inch cotton webbing straps were sewn onto the inside of the tote bag as straps.

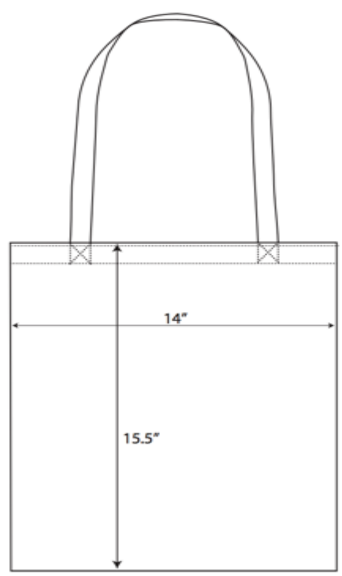

Figure 29. **Tote bag** Technical Flat.

3.5.4. Tote bag mordanting procedure.

The tote bags were mordanted using the steps found in 3.3.4 Mordant Procedure. The total amount of mordant was weighed out (7.1g), which was based on 10% (w/w).

3.5.5. Tote bag natural dyeing procedure.

To reduce energy used during this study, the extraction and dyeing process occurred simultaneously using the hot aqueous method. Due to the weight ratio of the tote bag to available plant material, the dye procedure for the tote bag deviated from the prescribed procedure found in 3.3.5, by using 50g of plant material to naturally dye the tote bag.

Tap water (5L) was boiled (100°C) using the double barrel boil method and 50g of plant material was heated in the pot for 10 minutes. The solution was cooled to 60°C and the previously mordanted tote bag was held in the dye solution for 15 minutes. The tote bag along with dye solution were placed in a plastic bag and allowed to stand overnight to achieve a darker shade of color. After 24 hours, the tote bag was washed with a pH neutral soap solution, rinsed thoroughly and air dried. The liquor to material ratio was 1:70 (Figure 30 and 31).

Figure 30. Natural Yellow Bag.

Figure 31. Natural Brown Bag.

3.5.6. Tote bag synthetic dyeing procedure.

A stock solution was created for the synthetic colors (Table 4). The dye solution was created by combining 45g of salt, and reactive dye amounts found in Tables 5 and 6 to 3L of cold water in a stainless- steel container. The solution was agitated for 10 minutes, then 5g of soda ash (Sodium carbonate) was added along with wetted tote bag. The double barrel boil method was used by placing the stainless -steel container in a kettle filled with water and heating it to 60°C for 10 minutes. 10g of soda ash was added and the solution was agitated for 15minutes. The tote bag was removed from the dye solution, washed and left to air dry. This procedure was used for both tan and yellow synthetic colors (Figure 32 and 33).

Figure 32. Synthetic Yellow Bag.

Figure 33. Synthetic Brown Bag.

Table 4. Stock Solution for Brown Synthetic Dye.

Remazol Dye	Amount of Powder Dyestuff (g)	Water (mL)
Yellow RR	0.1	100
Blue RR	0.1	100
Red RR	0.1	1000

Table 5. Synthetic Dye Solution – Brown.

Synthetic Color	Water (L)	Salt (g)	Soda Ash (g)	Remazol Yellow RR Stock Soln (g)	Remazol Blue RR Stock Soln (g)	Remazol Red RR Stock Soln (g)
Brown	3	45	15	43.765	15.54	76.91

Table 6. Synthetic Dye Solution – Yellow.

Synthetic Color	Water (L)	Salt (g)	Soda Ash (g)	Remazol Yellow 3GL powder (g)	Remazol Yellow RR Stock Soln (g)
Yellow	3	45	15	0.177	16.73

3.5.7. Survey development.

The questionnaire developed for this study contained thirty-four questions and was deployed on the survey software, Qualtrics.

The first section of the questionnaire collected demographic data that included age, gender, level of education and occupation. The second section surveyed participants' color response and aesthetic appeal when comparing naturally and synthetically dyed tote bags. Each question was measured using a five-point Likert scale ranging from 5-Very much dislike 1-Very much like.

The questions in the third section were developed using a previously tested and valid survey called Desire for Unique Consumer Products scale, which has been partially adapted to fit the context of this research. The following elements were measured; creative choice counter conformity, unpopular choice counter conformity and avoidance of similarity. Section three comprised four questions and used a five-point Likert scale ranging from 5-strongly agree to 1-strongly disagree, and undecided when applicable (Lynn & Harris, 1997).

Section four measured participants' intentions toward sustainability. The questions were developed using a scale from a current research-in progress studying Business Executive Green Behaviors: An Environmental theory of planned behavior (Mancha et al., 2014). The following factors were measured: green behavior intention response, green attitude response, green subjective norm response, and perceived behavioral control. All elements were measured on a five-point Likert scale ranging from 5-strongly agree to 1-strongly disagree, with the option to choose undecided and not applicable when necessary (See Appendix A for full questionnaire). This study utilized the Theory of Planned Behavior over other behavioral models because the model is found to be robust in examining a behavior with volitional control (Armitage et al., 1999).

3.5.8. Validity and reliability.

To ensure validity and reliability of the survey, a pilot test was conducted using a sample of five graduate students with knowledge of consumer research, behavior theory, and sustainability issues. Results of the pilot test led to the addition of sustainable lifestyle examples such as recycling, water conservation, for questions relating to intentions to reduce environmental impact.

3.5.9. IRB informed consent procedure.

A protocol procedure was developed (Appendix B) and was approved by the North Carolina State University's Institutional Review Board (IRB). The submission included all necessary documents including survey questions, interview and email communication script. Due to the nature of the research, the IRB reviewed the protocol and granted an exemption status on the requirement of signed consent form by participants. (Appendix B).

3.5.10. Survey setting.

The study took place on the campus of North Carolina State University, specifically in the Wilson College of Textiles atrium. The survey was conducted during the morning and ran until midafternoon.

3.5.11. Participant sample demographics.

The sampling procedure used in this study was a convenience sample. The participants were restricted to people in or passing through the Wilson College of Textiles Atrium at the time the study was set up, and who were willing to participate in the study in exchange for a tote bag as compensation. The sample included a total of 40 participants with 100% survey completion rate. There were 27 females (67.5%) and 13 males (32.5%). Of the total participants, the age ranges included 18-20 years (n = 6, 15%), 21-29 years (n = 29, 72.5%), 30-39 years (n = 2, 5%), 50-59 years (n = 1, 2.5%) and 60 years or older (n = 2, 5%). There were no participants in the 40 - 49 years age range. There were 36 students (90%), 3 Faculty (7.25%) and 1 staff person (2.4%). Participant level of education included high school diploma (n = 12, 30%), Bachelor's degree (n = 11, 27.5%), Master's degree (n = 12, 30%) and Doctorate (n = 5, 12.5%). The average score for Desire for Unique products was 3.875 with a standard deviation of 0.77. The average score for Planned Behavior Toward Sustainability was 3.814 with a standard deviation of 0.400.

3.5.12. Survey procedure.

The in-person survey was administered on March 19th until March 25th, 2019. Four tote bags were placed on a white table with Bag A, B, C, and D labels underneath each respective bag. People walking past were asked to volunteer for a 10-minute survey in exchange for compensation in the form of a tote bag. If the person agreed, they were explained the nature of the research, their participation was voluntary and they had the option to stop at any time. Information regarding anonymity, data collection and preservation was also explained. The participant was given the consent form and instructed to read it, and any further questions regarding the survey could be directed at the contact information located on the form. The survey was administered using Qualtrics, an online survey system. The participants used an iPad to complete the survey. Once the participant finished the first 3 sections, there was a brief explanation of the dye process for each tote bag. To ensure consistency of information, each participant was explained the dye process in the following manner.

- Bag A was dyed using yellow onion skins collected from Clark Dining Hall on NC States' main campus.
- Bag B was dyed using a combination of reactive dyes, RR, Remazol Blue RR and Remazol Red RR.
- Bag C was dyed using coffee grounds collected from Starbucks on NC States' main campus.
- Bag D was dyed using a combination of reactive dyes, Remazol Yellow RR and Remazol Yellow 3GL."

Following the dye application explanation, participants were asked to complete the remainder of the survey in which they responded to the color and visual appeal of each tote bag Treatment 2).

3.5.13. Data analysis.

The study's research phases were experimentally investigated. Phase one utilized descriptive statistics to describe the collections of data obtained from the various colorfastness color evaluation tests performed.

Phase two used a combination of descriptive and inferential statistics to analyze the data collected. Descriptive statistics were used to evaluate sample characteristics such as average score from participants Desire for Unique Consumer Products (DUCP) and Planned Sustainable Behavior (PSB) responses and frequency.

Inferential statistics used during the study included two sample mean t-tests, chi square tests, multivariate correlation analysis, and test reliability. Two sample mean t-tests were used to evaluate the differences in average DUCP and PSB scores when compared to choice of tote bag. Pearson's' chi-squared test was used to examine categorical difference such as participant visual appeal responses to the tote bags. Multivariate correlations analyses helped determine correlations between consumer behavior theories and tote bag choice. Test reliability was determined by utilizing Cronbach Alpha coefficient test, which examines multi-item constructs and determines internal consistency of participants' responses.

CHAPTER 4
RESULTS

4.1. Research Objectives

This study has two research objectives that were conducted in a two- phase process;

1. To extract natural dyes from pre-consumer food waste in order to dye a textile product.
2. To test consumer acceptance of the product using the Theory of Planned Behavior and Desire for Unique Consumer Products.

4.2. Research Hypotheses

Hypotheses:

H_{01}: Level of Desire for Unique Consumer Products will have no effect on the choice of bag during treatment 1 and 2.

Independent Variable: Level of Desire for Unique Consumer Products

Dependent Variable: Bag Choice

H_{02}: Level of Planned Sustainable Behavior will have no effect on the choice of bag during treatment 1 and 2.

Independent Variable: Level of Planned Sustainable Behavior

Dependent Variable: Bag Choice

H_{03}: Treatment 2 will have no effect on how participants' respond to the color to the bags during treatment 1 and 2.

Independent: Treatment 2

Dependent Variable: Color response to bag

H_{04}: Treatment 2 will have no effect on how participants' respond to the visual appearance of the bags during treatment 1 and 2.

Independent: Treatment 2

Dependent Variable: Visual Appeal response to bag

4.3. Phase One

Using restaurant pre-consumer food waste, natural dyes were extracted and a consumer product was dyed and evaluated against a synthetic dye comparison. In the results section, outcomes of Phase One AATCC tests and color evaluation are presented.

4.3.1. Collection, extraction and application.

The process of collecting pre-consumer food waste on a bi-weekly basis provided a sufficient amount of plant material for the samples dyed during this study. A noted limitation of the collection method involved inconsistency of preservation method on behalf of the restaurant or dining hall. However, once placed in a refrigerator, the onion skins would last up to three weeks in a plastic bag before mold began to grow. The coffee grounds did not exhibit this issue.

The simultaneous extraction and application method utilized during this study was satisfactory. The pre-consumer food waste was still intact and able to be composted at the local Food Waste Recycling Drop-off sites in Raleigh, North Carolina.

4.3.2. AATCC 8-2013 colorfastness to crocking.

The standard AATCC test evaluated the colorfastness properties of the dyed samples to rubbing. Three wet and dry trials were conducted on each sample and the average assigned color staining grades are shown in Table 7 and 8 respectively. The Active Standard ASTM D6554/D6554M for 100% cotton fabrics was used to rate colorfastness requirements for the samples dyed with natural materials. This standard was chosen as it was the standard that closely represented the 100% cotton duck canvas material used during this study. According to the standard, an acceptable colorfastness grade for dry crocking is a minimum grade of 4, and 1.5 for wet crocking. All naturally dyed samples met or exceeded the requirement for dry and wet crocking fastness.

Table 7. Gray Scale Analysis – Fastness to Crocking- Wet.

Sample	**Plant Material**	**Weight of Plant Material Used (g)**	**Water (mL)**	**Gray Scale Rating (wet) Trial 1**	**Gray Scale Rating (wet) Trial 2**	**Gray Scale Rating (wet) Trial 3**
K-001	Onion	10	1000	3-4	3-4	3-4
K-002	Onion	20	1000	3	3-4	3
K-003	Onion	40	1000	3-4	3-4	3
K-004	Coffee	10	1000	4-5	4-5	4-5
K-005	Coffee	20	1000	4	4	4-5
K-006	Coffee	40	1000	4	4	4
5-001	Onion	10	500	3-4	3-4	4
5-002	Onion	20	500	4-5	4	4-5
5-003	Onion	40	500	3-4	3-4	4
5-004	Coffee	10	500	4	4	4
5-005	Coffee	20	500	4	4	4-5
5-006	Coffee	40	500	4-5	4-5	4

Table 8. Gray Scale Analysis – Fastness to Crocking- Dry.

Sample	**Plant Material**	**Weight of Plant Material Used (g)**	**Water (mL)**	**Gray Scale Rating(dry) Trial 1**	**Gray Scale Rating(dry) Trial 2**	**Gray Scale Rating (dry) Trial 3**
K001	Onion	10	1000	5	5	5
K002	Onion	20	1000	5	4-5	5
K003	Onion	40	1000	5	5	4-5
K004	Coffee	10	1000	5	5	5
K005	Coffee	20	1000	4-5	4-5	5
K006	Coffee	40	1000	4-5	4-5	4-
5-001	Onion	10	500	5	5	5
5-002	Onion	20	500	5	5	4-5
5-003	Onion	40	500	4-5	4-5	4-5
5-004	Coffee	10	500	5	5	5
5-005	Coffee	20	500	4-5	4-5	5
5-006	Coffee	40	500	5	5	4-5

4.3.2.1. Wet crockfastness trial.

The samples dyed using onion skins had a consistently lower wet crocking rating (3, 3-4), than samples dyed using coffee grounds (4, 4-5). There is no trend in improvement of the wet crocking rating between varying amounts of plant material used. For the wet trials, it can be concluded that the samples dyed using onion skins have noticeable color transference to the rubbing of wet fabrics. While, samples dyed using coffee grounds displayed less color transference to rubbing of wet fabrics (Table 7).

4.3.2.2. Dry crockfastness trial.

All samples dyed with natural dyes have a high dry crocking rating (4-5, 5). There is no trend in improvement of the dry crocking rating between varying amounts of plant material used. For the dry trials, it can be concluded that all samples displayed less color transference to rubbing of dry fabrics (Table 8).

4.3.3. AATCC 61-2013 colorfastness to accelerated laundering.

The standard AATCC test **(61-2013)** evaluates colorfastness properties of textiles that are laundered often. For each dyed sample, three samples were measured and the averages are shown in Table 9. According to the Active Standard ASTMD6554/D6554M, an acceptable colorfastness grade for shade change and stain is a minimum grade of 3.5 and 3 respectively. All naturally dyed samples met or exceeded the requirement for stain but failed to meet the minimum requirement for shade change (ASTM International, 2014).

Table 9. Washing fastness of naturally dyed fabrics.

Trial	Washfastness Color Change	Color Stain Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
K001 Onion	1	5	3.5	4.5	5	5	5
K002 Onion	1	5	4	3.5	5	5	5
K003 Onion	1.5	4	3.5	2	4.5	5	5
K004 Coffee	1	5	5	4.5	5	5	5
K005 Coffee	1.5	5	4-5	4-5	5	5	5
K006 Coffee	1.5	4-5	4.5	4.5	5	5	5
5001 Onion	1	5	4	4.5	5	5	5
5002 Onion	1	5	4	5	5	5	5
5003 Onion	2	4.5	4.5	5	5	4.5	4.5
5004 Coffee	1.5	4-5	4-5	4-5	5	5	5
5005 Coffee	1.5	4-5	4-5	4-5	5	5	5
5006 Coffee	1.5	4-5	4-5	4-5	5	5	5

All naturally dyed samples exhibited below average (<3) color change. The onion dyed samples exhibited a grade of 1, with notable variations in trial 3 (grades of 2.5 and 3). The coffee dyed samples exhibited a rating of (1, 1.5). Change in color was significant in all samples, with onion dyed samples exhibiting a dramatic change in color following being washed followed by coffee dyed samples. Table 9 lists the acceptable staining grade for the multi-fiber strip. The results show that on average, both natural dyes do not heavily stain other fibers present in a wash cycle. There was a slight staining observed on the onion dyed sample. The natural dye effluent tended to stain the cotton and nylon fibers, while the coffee ground samples deposited almost no color on the multi-fiber strip. This can be seen in Table 9; on average, the coffee ground samples received a high color stain grade (>4.5). It can be concluded that the coffee ground dye deposits less color on fabrics in a wash cycle than the onion dyed samples.

4.3.4. Color evaluation of natural dyed samples.

Table 10 shows the CIELAB L*, a*, b* values for the fabrics dyed with different plant material and volumes of water. L*, a*, b* refers to the three axes of the CIELAB system. L* values represent perceived lightness of a color. The higher the L value, the lighter the color. As the L* value decreases, the colors appear darker. Each sample set exhibited a decrease in the L* value indicating as more plant material was used in the dye bath the sample achieved a darker color deposit. The a* axis indicates red and green colors. Each sample set exhibited an increase in the a*value indicating as more plant material was used in the dye bath, the sample appears to have more red colorant deposited. This is consistent with the plant material used, as both yellow onion and coffee grounds contain anthocyanin and tannins which carry red colorants. The b* axis represents yellow and blue colors. The onion skin dyed samples displayed more positive b*values indicating yellow, while the used coffee ground samples displayed b*values closer to 0, indicating more blue was deposited.

In conclusion, higher color depth was achieved using more plant material in the dye bath, in addition to color varieties seen in the a* and b* axis of the color spectrum.

Table 10. L*a*b* values for dyed samples.

Sample Number	Plant Material	Amount (g)	Water Amount (mL)	L*	a*	b*	Image
K -001	Onion	10	1000	75.7	4.54	53.53	
K- 002	Onion	20	1000	75.9	5.01	51.10	
K- 003	Onion	40	1000	72.4	6.98	58.27	
5- 001	Onion	10	500	82.7	-0.30	41.58	
5- 002	Onion	20	500	70.4	8.60	55.86	
5- 003	Onion	40	500	65.3	12.5	56.69	
K -004	Coffee	10	1000	78.72	4.51	7.93	
K - 005	Coffee	20	1000	78.59	4.50	8.43	
K- 006	Coffee	40	1000	77.1	4.59	10.80	
5-004	Coffee	10	500	79.60	4.52	7.40	
5- 005	Coffee	20	500	77.6	4.80	10.06	
5- 006	Coffee	40	500	75.81	5.06	10.72	

4.4. Phase Two

Consumer acceptance of the product was tested using the Theory of Planned Behavior and Desire for Unique Consumer Products for experimental treatment 1 and 2.

- Treatment 1 (T1): Participants were not subject to an explanation of the dye process of the textile products
- Treatment 2 (T2): Participants were subject to an explanation of dye process for textile products

4.4.1. Null hypothesis one: H_0: level of desire for unique consumer products (DUCP) will have no effect on the choice of bag.

The first null hypothesis of the research was to determine if a participant's level of desire for unique consumer products will have an effect on the choice of bag. When asked which bag was more visually appealing, participants who chose Bag A (natural yellow) vs. Bag B (synthetic yellow), and Bag C (natural brown) vs. Bag D (synthetic brown) were grouped and their DUCP scores were averaged for Treatment 1 and 2. A two sample mean t-test was performed to analyze whether DUCP score was different among the groups. The results suggested that none of the scores were statistically different at the .05 level of significance. (Tables 11 -14) Therefore the study failed to reject the null hypothesis. It can be concluded that a participant's level of desire for unique consumer products played no significant role on what bag they chose, during T1 or T2.

Table 11. Average DUCP score of Participants that chose Bag A or Bag B (Treatment 1).

Bag Choice	**Count of Choice (n)**	**Average PSB Score**	**Standard Dev.**
A (natural yellow)	16	4.093	0.4496
B (synthetic yellow)	22	3.7840	0.7952
t score	1.3972		
p value	**0.9145 > 0.05**		

*** accept null hypothesis*

Table 12. Average DUCP score of Participants that chose Bag A or Bag B (Treatment 2).

Bag Choice	Count of Choice (n)	Average PSB Score	Standard Dev.
A (natural yellow)	22	2.05682	0.52186
B (synthetic yellow)	16	3.64063	0.78546
t score	1.9642		
p value	**0.97 > 0.05**		

*** accept null hypothesis*

Table 13. Average DUCP score of Participants that chose Bag C or Bag D (Treatment 1).

Bag Choice	Count of Choice (n)	Average PSB Score	Standard Dev.
C (natural brown)	10	3.925	0.5814
D (synthetic brown)	30	3.858	0.7322
t score	0.263		
p value	**0.6027 > 0.05**		

*** accept null hypothesis*

Table 14. Average DUCP score of Participants that chose Bag C or Bag D (Treatment 2).

Bag Choice	Count of Choice (n)	Average PSB Score	Standard Dev.
C (natural brown)	17	4.16176	0.55532
D (synthetic brown)	21	3.58333	0.69579
t score	2.782		
p value	**0.9957 > 0.05**		

*** accept null hypothesis*

Relationship between DUCP score and color response, gender and level of education.

This subsection of the DUCP factor explored the relationship between participants' DUCP score and their color response to the tote bags during treatments 1 and 2. Additionally, the relationship between DUCP score and demographics such as gender and level of education was also compared.

Relationship between DUCP Score and color response.

A multivariate correlation analysis determined the r coefficient of DUCP score and color response. Tables 15 and 16 show the calculated correlations for color response for treatment 1 and 2.

Table 15. DUCP Score and Color Response Correlation for Treatment 1.

Scale	T1 Color Response Bag A (natural yellow)	T1 Color Response Bag B (synthetic yellow)	T1 Color Response Bag C (natural brown)	T1 Color Response Bag D (synthetic brown)
Desire for Unique Consumer Products Score	r = 0.2120	r = - 0.1119	r = 0.3626	r = - 0.0661

** *indicates a significant correlation coefficient*

Table 16. DUCP Score and Color Response Correlation for Treatment 2.

Scale	T2 Color Response Bag A (natural yellow)	T2 Color Response Bag B (synthetic yellow)	T2 Color Response Bag C (natural brown)	T2 Color Response Bag D (synthetic brown)
Desire for Unique Consumer Products Score	r = 0.2244	r = - 0.1044	r = 0.2815	r = 0.0460

** *indicates a significant correlation coefficient*

The results indicated there was no significant statistical correlation between participant DUCP score and color response to the dyed tote bags for Treatments 1 and 2. However, the correlations displayed 2 relational trends between DUCP score and color response.

Trend 1: DUCP Score ↑, Natural color response ↑ and Synthetic color response ↓

During treatment 1, a correlation analysis revealed a trend toward a positive relationship between the DUCP score and participants' response to the color of the natural dyed bags and negative relationship with the color of the synthetic dyed bags.

Trend 2: DUCP Score ↑, Natural and synthetic brown color response ↑ and Synthetic yellow color response ↓

During treatment 2, a correlation analysis revealed a trend toward a positive relationship between the DUCP score and participants' response to the color of the natural and synthetic brown bag, and negative relationship with the color of the synthetic yellow bag.

Relationship between DUCP score and gender.

A two sample mean t-test was performed in order to analyze whether DUCP score was different among genders. The results suggested that none of the scores were statistically different at the .05 level of significance (Tables 17). Therefore, it can be concluded that gender is not a predictor of DUCP Score.

Table 17. Average DUCP Score compared by Gender.

Gender	**Sample Size**	**Desire for Unique Consumer Products Average Score**	**Std. Dev**
Female	27	3.898	0.7273
Male	13	3.826	0.6308
t score	0.3054		
p value	**0.6191**		

*** indicates a significant difference*

Relationship between DUCP score and level of education.

A distribution of average DUCP scores in each education level was developed in order to determine any trends in the data set. Table 18 shows the average DUCP score decreases as education levels increase.

Table 18. Distribution of DUCP scores across Education Level.

Highest Education Level	**Desire for Unique Consumer Products Score average**	**Sample size**	**Std. Dev**
High school	4.33	12	0.4249
Bachelors	4.0	11	0.4885
Masters	3.479	12	0.81914
Doctoral	3.45	5	0.4847

4.4.2. Null Hypothesis Two: H_0: Level of Planned Sustainable Behavior (PSB) will have no effect on the choice of bag.

The second null hypothesis of the research was to determine if a participant's level of planned sustainable behavior will have no effect on the choice of bag. When asked which bag was more visually appealing, participants who chose Bag A (natural yellow) vs. Bag B (synthetic yellow), and Bag C (natural brown) vs. Bag D (synthetic brown) were grouped and their PSB scores were averaged for Treatment 1 and 2. A two sample mean t-test was performed to analyze whether PSB score was different among the groups. The results suggested that none of the scores were statistically different at the .05 level of significance. (Tables 19 -22) Therefore the study failed to reject the null hypothesis. It can be concluded that a participant's level of planned sustainable behavior played no significant role on what bag they chose.

Table 19. Average PSB score of Participants that chose Bag A or Bag B (Treatment 1).

Bag Choice	Count of Choice (n)	Average PSB Score	Standard Dev
A (natural)	16	3.905	0.4638
B (synthetic)	22	3.7845	0.3273
t score	0.9404		
p value	**0.8234 > 0.05**		

*** accept null hypothesis*

Table 20. Average PSB score of Participants that chose Bag A or Bag B (Treatment 2).

Bag Choice	Count of Choice (n)	Average PSB Score	Standard Dev.
A (natural yellow)	22	3.90454	0.4079
B (synthetic yellow)	16	3.70875	0.36027
t score	1.5327		
p value	**0.933 > 0.05**		

*** accept null hypothesis*

Table 21. Average PSB score of Participants that chose Bag C or Bag D (Treatment 1).

Bag Choice	Count of Choice (n)	Average PSB Score	Standard Dev.
C (natural brown)	10	3.849	0.4076
D (synthetic brown)	30	3.803	0.3908
t score	0.3191		
p value	**0.6243 > 0.05**		

*** accept null hypothesis*

Table 22. Average PSB score of Participants that chose Bag C or Bag D (Treatment 2).

Bag Choice	Count of Choice (n)	Average PSB Score	Standard Dev.
C (natural brown)	17	3.80882	0.3419
D (synthetic brown)	21	3.84095	0.427806
t score	1.5327		
p value	**0.933 > 0.05**		

*** accept null hypothesis*

Relationship between planned sustainable behavior (PSB) score and color response, gender and level of education.

This subsection of the PSB factor explored the relationship between participants' PSB score and their color response to the tote bags during treatments 1 and 2. Additionally, if there was any relationship between PSB score and demographics such as gender and level of education.

Relationship between PSB Score and color response.

A multivariate correlation analysis determined the r coefficient of PSB score and color response. Tables 23 and 24 show the calculated correlations for color response for treatment 1 and 2.

Table 23. PSB Score and Color Response Correlation for Treatment 1.

Scale	T2 Color Response Bag A (natural yellow)	T2 Color Response Bag B (synthetic yellow)	T2 Color Response Bag C (natural brown)	T2 Color Response Bag D (synthetic brown)
Planned Sustainable Behavior	r = 0.1225	r = 0.0191	r = 0.0130	r = - 0.0427

** *indicates a significant correlation coefficient*

Table 24. PSB Score and Color Response Correlation for Treatment 2.

Scale	T2 Color Response Bag A (natural yellow)	T2 Color Response Bag B (synthetic yellow)	T2 Color Response Bag C (natural brown)	T2 Color Response Bag D (synthetic brown)
Planned Sustainable Behavior	r = 0.1278	r =- 0.1591	r = 0.0359	r = - 0.1461

** *indicates a significant correlation coefficient*

The results indicated there was no significant statistical correlation between participant PSB score and color response to the dyed tote bags for Treatments 1 and 2. However, the correlations displayed 2 relational trends between DUCP score and color response.

Trend 1: ↑ PSB Score, ↑ Both Natural and synthetic yellow color response and ↓ Synthetic brown color response

During treatment 1, a correlation analysis revealed a trend toward a positive relationship between the PSB score and participants' response to the synthetic yellow bag and both natural dyed bags, and negative relationship with the synthetic brown bag.

Trend 2: ↑ PSB Score, ↑ Natural color response and ↓ Synthetic color response ↓

During treatment 2, a correlation analysis revealed a trend toward a positive relationship between the PSB score and participants' response to both natural dyed bags and negative relationship with both synthetic dyed bags.

Relationship between PSB score and gender.

A two sample mean t-test was performed in order to analyze whether PSB score was different among genders. The results suggested that none of the scores were statistically different at the .05 level of significance. (Tables 25). Therefore, it can be concluded that gender is not a predictor of PSB score.

Table 25. Average DUCP Score compared by Gender.

Gender	**Sample Size**	**Desire for Unique Consumer Products Average Score**	**Std. Dev**
Female	27	3.7962	0.4409
Male	13	3.8523	0.2751
t score	0.0.4917		
p value	**0.6872**		

*** indicates a significant difference*

Relationship between PSB score and level of education.

A simple distribution of average PSB scores in each education level was developed in order to determine any trends in the data set. Table 26 shows no common trend in average PSB score as education levels increase or decreases.

Table 26. Distribution of PSB scores across Education Level.

Highest Education Level	Desire for Unique Consumer Products Score average	Sample size	Std. Dev
High school	3.7258	12	0.4249
Bachelors	3.863	11	0.4885
Masters	3.805	12	0.81914
Doctoral	3.916	5	0.4847

4.4.3. Null Hypothesis Three: H_0: Treatment 2 will have no effect on participants' color response to the bags.

The third null hypothesis of the research was to determine if Treatment 2 will have an effect on participants' color response to the bags. Following treatment 2 (dye treatment explanation), participants were asked to respond to the color of Bags A (natural yellow), B (synthetic yellow), C (natural brown) and D (synthetic brown). Color responses ranged from (low) 1 to (high) 5. The color responses were averaged for Treatment 1 and 2 for each bag. A paired t-test was performed to analyze whether there was a significant difference in responses. The results suggest that there were extremely statistically significant differences in color responses from Treatment 1 to 2 with Bag A, B and D but not bag C. The results in Table 27 show that on average, participants had a higher color response score to the natural dyed bags and a lower color response to the synthetic dyed bags, following Treatment 2. Therefore, the study rejected the null hypothesis. It can be concluded that Treatment 2 plays a significant role in participants' color response to the natural yellow, natural brown and synthetic brown bags.

Table 27. Average Color Response Difference of Bags A, B, C and D.

Bag Type	Treatment 1 Color response mean	Treatment 2 Color response mean	Mean Difference	p value
Bag A (natural yellow)	3.05	3.95	+0.9	**0.00012****
Bag B (synthetic yellow)	3.6	3.275	-0.325	0.5384
Bag C (natural brown)	2.825	3.3775	+0.95	**0.00001****
Bag D (synthetic brown)	4.025	3.45	-0.575	**0.0011****

*** indicates significant difference*

4.4.4. Null Hypothesis Four: H_0: Treatment 2 will have no effect on participants' response to the bags' visual appeal.

The final null hypothesis of the research considered whether Treatment 2 would have an effect on visual appeal responses. Following Treatment 2, participants were asked which bag was more visually appealing. Due to the categorical nature of the responses, a Chi-Squared test was performed. Results indicated an extremely significant statistical difference in visual appeal response of Bag A vs. Bag B and Bag C vs Bag D respectively ($\chi2$ = 29.793, 12.332; $p < 0.001$, $p < 0.0012$) (Table 28).

Table 28. Visual Appeal Response Difference of Bags A, B, C and D.

Bag Type	Treatment 1 Visual Appeal Response Total %	Treatment 2 Visual Appeal Response Total %		
Bag A (natural yellow)	40%	55%		
Bag B (synthetic yellow)	55%	40%	**$\chi 2$**	**p < ChiSq**
			29.793	**p < 0.001****
Bag C (natural brown)	25%	42.50%		
Bag D (synthetic brown)	75%	52.50%		
			$\chi 2$	**p < ChiSq**
			12.332	**p < 0.0012****

*** indicates < 0.005*

It was concluded, after treatment 2, more participants found the natural yellow bag more visually appealing than the synthetic yellow bag. Even though there is a significant difference in visual appeal response between treatment 1 and treatment 2 for bags C and D, more participants still found the synthetic brown bag more visually appealing. Therefore, the study rejected the null hypothesis. It can be concluded that Treatment 2 plays a significant role in participants' visual appeal response to the bags.

4.4.5. Relationship between DUCP and PSB scores.

In order to determine a relationship between the scores, a multivariate correlation analysis determined the r coefficient of DUCP and PSB scores. Table 29 shows the calculated correlations for both scores. Based on the low r coefficient, it can be concluded that there is no significant statistical correlation between a participant's behavior toward sustainability and their desire for unique consumer products. The two behavior predicting factors are not linked in participants. However, a correlation analysis revealed a trend toward a positive relationship between the two factors.

Table 29. DUCP and PSB Relationship.

Scale	**Planned Sustainable Behavior**
Desire for unique consumer products	r = 0.1253

***indicates significant correlation*

4.4.6. Reliability of the DUCP and PSB scale.

Test reliability was determined by utilizing Cronbach Alpha coefficient test, which examines multi-item constructs and determines internal consistency of participants' responses. Table 30 shows the overall reliability of the scales. The Behavior Toward Sustainability displayed a reliable internal consistency output of 0.7264, which is above the 0.70 threshold of reliability. However, the Desire for Unique Consumer Products displayed a Cronbach Alpha value of 0.6784, which is below the 0.70 threshold of reliability. This could be due to a small number of questions in the set, or poor wording of questions which lead participants to have a wide range of different responses.

Table 30. Overall Scale Reliability.

Category	**Entire Set Cronbach alpha**	**Internal Consistency Reliable = >.70**	**Internal Reliability of Scale**
Desire for Unique Consumer Products Scale	0.6784	.70	Not reliable
Planned Sustainable Behavior	0.7264	.70	Reliable

CHAPTER 5
DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1. Phase One Discussion

This section will be discussing the results from phase one of the research that included plant material collection, extraction and colorfastness evaluation tests.

5.1.1. Natural dye collection, extraction and application.

The collection process of pre-consumer food waste utilized during this study was sufficient for small scale production. However, the process can be streamlined by collecting all plant materials from one site. Retailers interested in large scale production using this type of alternative plant material are able to benefit from this process by working to improve their environmental impact in relation to dyeing. The extraction and application procedure selected for this study produced fabrics samples that were dyed. The colorfastness properties and application evenness on the fabric could be analyzed for improvement. In addition, the supply chain would need to be examined for efficiency and replicability.

5.1.2. Colorfastness to crocking evaluation.

Based on the results from the colorfastness to crocking evaluation, it can be concluded that the samples dyed with natural materials had an acceptable (≥ 3) dry and wet colorfastness rating. The samples dyed using onion skins exhibited the most color transfer when rubbed with a wet crock square. This could be caused by excess dye colorants sitting on top of the fiber. The samples also displayed more color transference when rubbed with a dry fabric sample. The samples dyed using used coffee grounds displayed above average (≥ 4) colorfastness score, meaning there was low color transfer to both wet and dry rubbing. As a result, it can be concluded that the coffee grounds have better color crockfastness than the onion skins.

5.1.3. Colorfastness to laundering evaluation.

Both natural dye samples displayed low color deposition on other fibers present in a wash cycle. Based on the results from the colorfastness to laundering evaluation, it can be concluded that the natural dyed samples had an acceptable (> 3) color staining rating. Overall the coffee ground samples displayed a half step better shade change rating (1.5) compared to the onion skin rating (1.0). However, both onion skin and coffee ground samples lost a significant amount of color when laundered. These results concluded neither natural dyes displayed adequate colorfastness to laundering and should not be applied to products that are washed often. Further research and testing should be done to address this issue. Product developers should take this information into consideration when deciding what products this alternative form of dye is applied to.

5.1.4. Color evaluation.

Both sets of dyed samples exhibited depth of shade progression when L* values were evaluated. For both the onion skin and coffee grounds, increased plant material amount contributed to darker shades. It is important to know that pre-consumer food waste plant material is able to achieve a variety of shade and color levels.

5.2. Phase Two Discussion

This section will be discussing the results from phase two of the research that included consumer evaluation of the tote bags.

5.2.1. Consumer evaluation of naturally dyed tote bags.

The study found that levels of Desire for Unique Consumer Product and Planned Sustainable Behavior were not predictive factors in tote bag choice. However, the study demonstrated that process explanation affected product choice in the following way; after treatment 2 (dye process explanation), there was a significant positive shift in consumer opinion toward the naturally dyed tote bags, seen in an increase in positive color response and visual appeal. In addition, respondents anecdotally explained that once they knew how the natural bags were dyed, it changed their opinion. Respondents described the initial characteristics of the tote bags as “blotchy”, “uneven”, and “dirty”. This language then changed to “novel” and “tie-dye” after learning about the recycled food waste that dyed the product. It can be concluded that taking time to educate consumers on sustainable products has a positive impact on consumer opinion and product choice.

It should be noted that the synthetically dyed brown bag had broad appeal, independent of demographics. During Treatment 1 and 2, the tote bag received high visual appeal responses. This could be caused by the bags’ even generic color.

A slight trend was determined when education level and desire for unique products score was compared. The more education a participant obtained, the lower their desire for unique products became. Education level is generally synonymous with age, therefore a slight relationship between age, education level and desire for unique products can be found. This finding could be of interest to retailers determining their target market for naturally dyed products.

5.2.2 Reliability of tests.

The consumer behavior theories utilized for this study found no relationship between behavior and product choice. This finding is not consistent with the research currently available. For future research the study could be improved in the following ways, survey more participants, different behavior theories examining a different aspect of product choice, evaluate question phrasing, and the addition of noticeable characteristics in the products being evaluated.

For example, the naturally dyed tote bag could have been dyed with traditional hand dye techniques to elevate the "uniqueness" factor.

5.3. Recommendations for Future Research

There is room for improvement in colorfastness of natural dyes extracted from food waste before further application is done with a wider range of textile products. Currently, the poor colorfastness to wet rubbing and laundering reduce the product application potentials. Further research should also be conducted into consumer acceptance of variability of colorfastness in natural dyes. Evaluating the total environmental impact of the process was beyond the scope of this study. However, research into environmental trade-offs using food waste natural dye compared to a standard synthetic dye process would be important to measure the feasibility of the natural dye process for consumer products. An in-depth qualitative study can examine the reasons behind why a consumer made the product choices, and how the dye process explanation changed or did not affect their opinion toward the naturally dyed product.

REFERENCES

AATCC. Colorfastness to crocking: AATCC crockmeter method (TM 8-2007). AATCC Technical Manual. 2007:17-19.

AATCC. Colorfastness to laundering: Accelerated (TM 61-2010). AATCC Technical Manual. 2010:86-90.

AATCC. Gray scale for color change (EP 1-2007). AATCC Technical Manual. 377-378.

AATCC. Gray scale for staining (EP 2-2007). AATCC Technical Manual. 2007:381-382.

AATCC. Instrumental assessment of the change in color of a test specimen (EP 7-2006). AATCC Technical Manual. 392-393.

AATCC. Instrumental color measurement (EP 6-2007). AATCC Technical Manual. 007:384-389.

Ajzen, I. (1991) The theory of planned behavior, *Organizational Behavior and Human Decision Processes, 50*(2), pp. 179-211.

Ajzen, I. (2012). The Theory of Planned Behavior. *Handbook of Theories of Social Psychology: Volume 1,*438-459. doi:10.4135/9781446249215.n22

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology,22*(5), 453-474. doi:10.1016/0022-1031(86)90045-4

Amlinger, F., Peyr, S., & Cuhls, C. (2008). Greenhouse gas emissions from composting and mechanical biological treatment. *Waste Management & Research,26*(1), 47-60. doi:10.1177/0734242x07088432

Armitage, C. J., & Conner, M. (1999). The theory of planned behaviour: Assessment of predictive validity and perceived control. British Journal of Social Psychology, 38(1), 35-54. doi:10.1348/014466699164022.

ASTM International. ASTM D6554/D6554M-14 Standard Specification for 100% Cotton Denim Fabrics. West Conshohocken, PA; ASTM International, 2014 doi: https://doi-org.prox.lib.ncsu.edu/10.1520/D6554M-14

Ayres, R. U. (2004). On the life cycle metaphor: Where ecology and economics diverge. *Ecological Economics,48*(4), 425-438. doi:10.1016/j.ecolecon.2003.10.018

Azwanida, N. (2015). A Review on the Extraction Methods Use in Medicinal Plants, Principle, Strength and Limitation. *Medicinal & Aromatic Plants, 04*(03). doi:10.4172/2167-0412.1000196.

Basic Information about Landfill Gas. (2019, April 09). Retrieved from https://www.epa.gov/lmop/basic-information-about-landfill-gas

Bavas, J. (2014, May 28). Government considers banning 'carcinogenic' dyes. Retrieved from https://www.abc.net.au/news/2014-05-28/govt-considers-banning-carcinogenic-dyes-more-found-in-clothing/5482040

Bechtold, T. , Mahmud- Ali, A. and Mussak, R. A. (2007), Reuse of ash- tree (*Fraxinus excelsior L.*) bark as natural dyes for textile dyeing: process conditions and process stability. *Coloration Technology, 123*: 271-279. doi:10.1111/j.1478-4408.2007.00095.x

Bechtold, T., Mussak, R., Mahmud-Ali, A., Ganglberger, E., & Geissler, S. (2006). Extraction of natural dyes for textile dyeing from coloured plant wastes released from the food and beverage industry. *Journal of the Science of Food and Agriculture,86*(2), 233-242. doi:10.1002/jsfa.2360.

Boldrin, A., Andersen, J. K., Møller, J., Christensen, T. H., & Favoino, E. (2009). Composting and compost utilization: Accounting of greenhouse gases and global warming contributions. *Waste Management & Research,27*(8), 800-812. doi:10.1177/0734242x09345275

Cañamares, M. V., Reagan, D. A., Lombardi, J. R., & Leona, M. (2014). TLC-SERS of mauve, the first synthetic dye. Journal of Raman Spectroscopy, 45(11-12), 1147-1152. doi:10.1002/jrs.4508.

Cannon, J., Cannon, M., & Dalby-Quenet, G. (1994). *Dye plants and dyeing*. Portland: Timber Press in association with the Royal Botanic Gardens Kew.

Cao, H., Scudder, C., Howard, C., Piro, K., Tattersall, H., & Frett, J. (2014). Locally produced textiles: Product development and evaluation of consumers' acceptance. *International Journal of Fashion Design, Technology and Education,7*(3), 189-197. doi:10.1080/17543266.2014.950347

Cardello, A. V., Pineau, B., Paisley, A. G., Roigard, C. M., Chheang, S. L., Guo, L. F., & Jaeger, S. R. (2016). Cognitive and emotional differentiators for beer: An exploratory study focusing on "uniqueness". *Food Quality and Preference,54*, 23-38. doi:10.1016/j.foodqual.2016.07.001

Carpenter, G. S., Glazer, R., & Nakamoto, K. (1994). Meaningful brands from meaningless differentiation: The dependence on irrelevant attributes. *Journal of Marketing Research, 31*(3), 339–350.

Chenciner, R. (2000). *Madder red: A history of luxury and trade: Plant dyes and pigments in world commerce and art*. Abingdon, Oxon: Routledge.

Costello, C., Birisci, E., & Mcgarvey, R. G. (2015). Food waste in campus dining operations: Inventory of pre- and post-consumer mass by food category, and estimation of embodied greenhouse gas emissions. *Renewable Agriculture and Food Systems, 31*(03), 191-201. doi:10.1017/s1742170515000071.

Dean, J. (2010). *Wild color: The complete guide to making and using natural dyes*. New York, NY: Watson-Guptill Publications.

DeBell, J., Erlich, O., Mirza, A., & Runyon Sr., A. (2002). Colorado Institutional Food Waste Composting Guide. http://ecenter.colorado.edu/files/77342c92dbad96e181e5ea3805db9a1dbf39441d.pdf: University of Colorado Recycling Services.

Ding, Y., & Freeman, H. S. (2017). Mordant dye application on cotton: Optimisation and combination with natural dyes. *Coloration Technology, 133*(5), 369-375. doi:10.1111/cote.12288

Dry wet rubbing fastness tester AATCC Manual Crockmeter Rub and color transfer testing Color fastness tester. (n.d.). Retrieved from https://www.amazon.com/rubbing-fastness-Crockmeter-transfer-testing/dp/B00XC1KANQ

Edwards, D., Williams, C., (2011). Method for Estimating Greenhouse Gas Emission Reductions from Compost from Commercial Organic Waste. from: http://www.arb.ca.gov/cc/protocols/localgov/pubs/compost_method.pdf (accessed 15.03.19.)

Eifler, C., & Diekamp, K. (2013). Consumer Acceptance of Sustainable Fashion in Germany. *Research Journal of Textile and Apparel,17*(1), 70-77. doi:10.1108/rjta-17-01-2013-b007

Favoino, E., & Hogg, D. (2008). The potential role of compost in reducing greenhouse gases. *Waste Management & Research, 26*(1), 61-69. doi:10.1177/0734242x08088584

Forbes, R. J. (1964). *Studies in ancient technology*. Leiden, Netherlands: E.J. Brill.

Garfield, S. (2002). *Mauve: How one man invented a color that changed the world*. New York, NY: W.W. Norton & Company.

Gilbert (nee Stoker), K.G. & Cooke, D.T. (2001) Dyes from Plants: Past usage, present understanding and potential. *Plant Growth Regulation,34*(1) 57- 69 https://doi.org/10.1023/A:1013374618870

Goldsmith, R. E., Clark, R. A., & Goldsmith, E. B. (2014). The Desire for Unique Consumer Products, Innovativeness, and Conformity. *Developments in Marketing Science: Proceedings of the Academy of Marketing Science Proceedings of the 2007 Academy of Marketing Science (AMS) Annual Conference,* 206-210. doi:10.1007/978-3-319-11806-2_96

Griesbach, R. J. (2005). *Plant Breeding Reviews* (Vol. 25) (J. Janick, Ed.). Hoboken, NJ: Wiley.

Grolleaud, M. (2002). Post-harvest losses: *Discovering the full story. Overview of the phenomenon of losses during the Post-harvest System*. Retrieved from http://www.fao.org/DOCREP/004/AC301E/AC301e00.htm

Hall, K. D., Guo, J., Dore, M., & Chow, C. C. (2009). The Progressive Increase of Food Waste in America and Its Environmental Impact. *PLoS ONE,4*(11). doi:10.1371/journal.pone.0007940

Handa, S. S., Khanuja, S. P., Longo, G., & Rakesh, D. D. (2008). *Extraction technologies for medicinal and aromatic plants*. Trieste (Italy): Earth, Environmental and Marine Sciences and Technologies.

Hinks, D., & Shamey, R. (2011). Review of retail store lighting: Implications for colour control of products. *Coloration Technology,127*(2), 121-128. doi:10.1111/j.1478-4408.2011.00286.x

Jin, B., & Son, J. (2014). Face saving, materialism, and desire for unique apparel products: Differences among three Asian countries. *The Journal of The Textile Institute, 105*(3), 304-313. doi:10.1080/00405000.2013.839352

Julkunen-Tiitto, R., & Hggman, H. (2009). Tannins and Tannin Agents. *Handbook of Natural Colorants,*201-219. doi:10.1002/9780470744970.ch12.

Kamatar, M. (2013). Natural Food colouring: A healthier alternative to artificial food colouring: Proceedings from Global Milling Conference: Safety, sustainability and food supply for the 21st century. Chennai, India

Keiser, S., Vandermar, D., & Garner, M. (2017). *Beyond Design* (4th ed.). NEW YORK, New York: Fairchild Books.

Ko, S. B., & Jin, B. (2017). Predictors of Purchase Intention toward Green Apparel Products: A Cross-Cultural Investigation in the U.S. and China. Journal of Fashion Marketing and Management: An International Journal, 21(1), 70-87. doi:https://doi.org/10.1108/ JFMM-07-2014-0057

Koren, Z.C. (1993). The Colors and Dyes on Ancient Textiles in Israel. In Sorek C. and Ayalon E. (eds.) *Colors from Nature: Natural Colors in Ancient Times*, Eretz Israel Museum, Tel Aviv, pp. 15*-31. Kuehni, R. G. (2013). *Color: An introduction to practice and principles*. Hoboken, NJ: Wiley.

Lee, Y. (2006). Dyeing, fastness, and deodorizing properties of cotton, silk, and wool fabrics dyed with coffee sludge (Coffea arabica L.) extract. *Journal of Applied Polymer Science, 103*(1), 251-257. doi:10.1002/app.25221.

Levis, J., Barlaz, M., Themelis, N., & Ulloa, P. (2010). Assessment of the state of food waste treatment in the United States and Canada. *Waste Management,30*(8-9), 1486-1494. doi:10.1016/j.wasman.2010.01.031

Lynn, M., & Harris, J. (1997). The desire for unique consumer products: A new individual differences scale. *Psychology & Marketing, 14*(6), 601-616. Retrieved from https://proxying.lib.ncsu.edu/index.php/login?url=https://search.proquest.com/docview/227740677?accountid=12725

Mancha, R.; Muniz, K.; & Yoder, C. Studying Executives' Green Behaviors: An Environmental Theory of Planned Behavior. Unpublished Manuscript. 2014. Available online: http://aisel.aisnet.org/cgi/ viewcontent.cgi?article=1574&context=amcis2014 (accessed on 27 January 2019).

Martínez-Blanco, J., Lazcano, C., Christensen, T. H., Muñoz, P., Rieradevall, J., Møller, J., . . . Boldrin, A. (2013). Compost benefits for agriculture evaluated by life cycle assessment. A review. *Agronomy for Sustainable Development,33*(4), 721-732. doi:10.1007/s13593-013-0148-7

McLaren, K. (1986). *The colour science of dyes and pigments*. Bristol: Hilger.

Mills, J. S., & White, R. (1987). Dyestuffs and other coloured materials. *The Organic Chemistry of Museum Objects,*121-133. doi:10.1016/b978-0-408-11810-1.50015-5.

Montazer, M., Parvinzadeh, M., & Kiumarsi, A. (2004). Colorimetric properties of wool dyed with natural dyes after treatment with ammonia. *Coloration Technology,120*(4), 161-166. doi:10.1111/j.1478-4408.2004.tb00223.x

Morris, P., & Travis, A. (1992). A History of the International Dyestuff Industry, *American Dyestuff Reporter, 81*(11), 59.

Municipal Solid Waste (MSW) in the United States: Facts and Figures (2010) from EPA:http://www.epa.gov/osw/nonhaz/municipal/pubs/msw2009rpt.pdf (accessed 25.01.12.)

Nagendrappa, G. (2010). Sir William Henry Perkin: The man and his 'Mauve'. *Resonance,15*(9), 779-793. doi:10.1007/s12045-010-0088-3.

Narvekar, M. S., & Srivastava, A. K. (2002). Separation of banned amine isomers in relation to German ban on azo dyes by derivatization on GC-MS. *Chromatographia,55*(11-12), 729-735. doi:10.1007/bf02491789

Overview of the electromagnetic spectrum and electromagnetic source in the present study (Reprinted from Louis E. Keiner, Coastal Carolina University) (http://en.wikipedia.org/wiki/Electromagnetic_ spectrum)

Panche, A. N., Diwan, A. D., & Chandra, S. R. (2016). Flavonoids: an overview. *Journal of nutritional science*, *5*, e47. doi:10.1017/jns.2016.41.

Penney, D, P. (2000). "A brief history of the Biological Stain Commission: its founders, its mission and the first 75 years". *Biotechnic & histochemistry : official publication of the Biological Stain Commission* (1052-0295), *75* (4), p. 15

Platzek, T., Lang, C., Grohmann, G., Gi, U., & Baltes, W. (1999). Formation of a carcinogenic aromatic amine from an azo dye by human skin bacteria in vitro. Human & Experimental Toxicology, 18(9), 552-559. doi:10.1191/096032799678845061

Räisänen, R. (2018). Fungal colorants in applications - focus on Cortinarius species. *Coloration Technology,135*(1), 22-31. doi:10.1111/cote.12376.

Robinson, S. (1969). *A history of dyed textiles: Dyes, fibres, painted bark, batik, starch-resist, discharge, tie-dye, further sources for research*. Cambridge, MA: M.I.T. Press.

Rodriguez-Amaya, D. B. (2016). Natural food pigments and colorants. *Current Opinion in Food Science, 7*, 20-26. doi:10.1016/j.cofs.2015.08.004

Ryan, J., M., Bonfield, & H., E. (1975, January 01). The Extended Fishbein Model: Additional Insights...And Problems. Retrieved from http://www.acrwebsite.org/volumes/5769/volumes/v02/NA-02

Saer, A., Lansing, S., Davitt, N. H., & Graves, R. E. (2013). Life cycle assessment of a food waste composting system: Environmental impact hotspots. *Journal of Cleaner Production, 52*, 234-244. doi:10.1016/j.jclepro.2013.03.022

Salazar, H.A.; Oerlemans, L.; van Stroe-Biezen, S. Social influence on sustainable consumption: Evidence from a behavioural experiment. Int. J. Consum. Stud. 2013, 37, 172–180.

Samanta, A.K. and Agarwal, P. (2009) Application of Natural Dyes on Textiles. *Indian Journal of Fibre and Textile Research, 34*, 384-399.

Samanta, A. K., & Konar, A. (2011). Dyeing of Textiles with Natural Dyes. *Natural Dyes*. doi:10.5772/21341

Sarkar, A. K. (2007). On the relationship between fabric processing and ultraviolet radiation transmission. *Photodermatology, Photoimmunology & Photomedicine, 23*(5), 191-196. doi:10.1111/j.1600-0781.2007.00306.x

Sarkar, A. K., & Seal, C. M. (2003). Color Strength and Colorfastness of Flax Fabrics Dyed with Natural *Colorants. Clothing and Textiles Research Journal, 21*(4), 162–166. https://doi.org/10.1177/0887302X0402100402

Sathianarayanan, M.P., Bhat, N., Kokate, S.S., & Walunj, V.E. (2010). Antibacterial finish for cotton fabric from herbal products. *Indian Journal of Fibre and Textile Research*. *35 (1)*. 50-58.

Savvidis, G., Zarkogianni, M., Karanikas, E., Lazaridis, N., Nikolaidis, N., & Tsatsaroni, E. (2013). Digital and conventional printing and dyeing with the natural dye annatto: Optimisation and standardization processes to meet future demands. *Coloration Technology,129*(1), 55-63. doi:10.1111/cote.12004

Shahid, M., Shahid-Ul-Islam, & Mohammad, F. (2013). Recent advancements in natural dye applications: A review. *Journal of Cleaner Production, 53*, 310-331. doi:10.1016/j.jclepro.2013.03.031

Singh, R., Jain, A., Panwar, S., Gupta, D., & Khare, S. (2005). Antimicrobial activity of some natural dyes. *Dyes and Pigments,66*(2), 99-102. doi:10.1016/j.dyepig.2004.09.005

Sinha, K., Saha, P. D., & Datta, S. (2012). Response surface optimization and artificial neural network modeling of microwave assisted natural dye extraction from pomegranate rind. *Industrial Crops and Products, 37*(1), 408-414. doi:10.1016/j.indcrop.2011.12.032

Snyder, C. R., & Fromkin, H. L. (1977). Abnormality as a positive characteristic: The development and validation of a scale measuring need for uniqueness. *Journal of Abnorma1 Psychology, 86*(5) 18- 527

Snyder, C.R. and Fromkin, H.L. (1980) Uniqueness: The human pursuit of difference. Plenum Press, New York.

Sugar, M., & Myers, W. R. (2002). *The complete natural dyeing guide*. Lemoyne, PA: Rug Hooking.

Sukenik, N., Iluz, D., Amar, Z., Varvak, A., Workman, V., Shamir, O., & Ben-Yosef, E. (2017). Early evidence (late 2nd millennium BCE) of plant-based dyeing of textiles from Timna, Israel. *Plos One, 12*(6). doi:10.1371/journal.pone.0179014.

Tang, R., Tang, H., & Yang, C. (2010). Adsorption Isotherms and Mordant Dyeing Properties of Tea Polyphenols on Wool, Silk, and Nylon. *Industrial & Engineering Chemistry Research,49*(19), 8894-8901. doi:10.1021/ie100052b

Tepper, K. (1996), Understanding Consumers Counter conformity Behavior: A Critical Appraisal of Trait Measures Employed in Nonconformity Research, in Enhancing Knowledge of Development in Marketing, ed. Anthony Benedetto et al., Chicago: American Marketing Association, 252–257.

Thompson, C., & Haytko, D. (1997). Speaking of Fashion: Consumers Uses of Fashion Discourses and the Appropriation of Countervailing Cultural Meanings. *Journal of Consumer Research,24*(1), 15-42. doi:10.1086/209491

Tian, K. T., Bearden, W. O., & Hunter, G. L. (2001). Consumers' need for uniqueness: Scale development and validation. *Journal of Consumer Research, 28*(1), 50-66.

Thoradeniya, P., Lee, J., Tan, R., & Ferreira, A. (2015). Sustainability reporting and the theory of planned behaviour. *Accounting, Auditing & Accountability Journal, 28*(7), 1099-1137. doi:10.1108/aaaj-08-2013-1449

United Nations. World Summit on Sustainable Development: Johannesburg 2002.

United States International Trade Commission. (1981). U.S. SYNTHETIC ORGANIC DYE INDUSTRY: ITS COMPETITIVENESS IN THE WORLD MARKET, Investigation No. 332-120 Under Section 332 of the Tariff Act of 1930**.** retrieved from https://www.usitc.gov/publications/332/pub1166.pdf

United States Environmental Protection Agency Basic Information about Food Waste (2011) from EPA: http://www.epa.gov/osw/conserve/materials/organics/food/fd-basic.html (accessed 25.01.12.)

Vankar, P. S. (2007). *Handbook on natural dyes for industrial applications*. Delhi, India: National Institute of Industrial Research.

Wickens, H. (1990). *Natural dyes for spinners & weavers*. London, GB: BT Batsford Limited.

Wier, M., O'Doherty Jensen, K., Anderson, L. M., & Millock, K. (2008). The character of demand in mature organic food markets: Great Britain and Denmark compared. *Food Policy, 33*(5), 406–421

Yaseen, D. A., & Scholz, M. (2018). Treatment of synthetic textile wastewater containing dye mixtures with microcosms. *Environmental Science and Pollution Research,25*(2), 1980-1997. doi:10.1007/s11356-017-0633-7

Yi, E., & Cho, J. (2008). Color analysis of natural colorant-dyed fabrics. *Color Research & Application,33*(2), 148-157. doi:10.1002/col.20390

Yusuf, M., Shabbir, M., & Mohammad, F. (2017). Natural Colorants: Historical, Processing and Sustainable Prospects. *Natural Products and Bioprospecting*, *7*(1), 123–145. http://doi.org/10.1007/s13659-017-0119-9.

Zarkogianni, M., Mikropoulou, E., Varella, E., & Tsatsaroni, E. (2010). Colour and fastness of natural dyes: Revival of traditional dyeing techniques. *Coloration Technology,127*(1), 18-27. doi:10.1111/j.1478-4408.2010.00273.x

Zheng, G. H., Fu, H. B., & Liu, G. P. (2011). Application of rare earth as mordant for the dyeing of ramie fabrics with natural dyes. *Korean Journal of Chemical Engineering,28*(11), 2148-2155. doi:10.1007/s11814-011-0090-9

APPENDICES

Appendix A – Questionnaire

1. **Which category includes your age?**

18-20
21-29

30-39

40-49

50-59

60 or older

2. **What is your Occupation?**

Student
Faculty
Staff
Other

3. **With what gender label do you most closely identify?**

Male
Female
Gender non-conforming
Prefer not to specify

4. **What is you highest level of educational achievement?**

Highschool Diploma
Bachelors Degree
Masters degree
Doctoral

5. **What is your response to the color of Bag A**

1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

6. **What is your response to the color of Bag B**

1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

7. **Which bag is more aesthetically pleasing?**

Bag A or Bag B

8. **What is your response to the color of Bag C**

1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

9. **What is your response to the color of Bag D**

1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

10. Which bag is more aesthetically pleasing?
Bag C or Bag D

11. I enjoy having things that others do not
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

12. I would prefer to have things custom-made than to have them ready-made
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

13. I enjoy shopping at stores that carry merchandise which is different and unusual.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

14. I am not very attracted to rare objects.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

15. I am confident that I can protect the environment
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

16. I am not good at leading a green lifestyle.
1 Strongly Disagree • 2 Disagree • 3 Not Applicable • 4 Agree • 5 Strongly Agree

17. I believe I have the ability to reduce my carbon footprint.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

18. I have resources, time and willingness to live an environmentally friendly lifestyle
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

19. I will try to reduce my carbon footprint in the forthcoming month.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

20. I intend to engage in environmentally-friendly behavior in the forthcoming month.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

21. I would like to join and actively participate in an environmentalist group.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

22. Protecting the environment is more important than protecting peoples' jobs.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

23. I try to save natural resources.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

24. Most people who are important to me do not want me to be environmentally friendly.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

25. Most people whose opinion I value think that it is important to reduce waste.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

26. Most people who I respect and admire engage in environmentally friendly behaviors.
1 Strongly Disagree • 2 Disagree • 3 Undecided • 4 Agree • 5 Strongly Agree

[Break for explanation]

27. What is your response to the color of Bag A
1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

28. What is your response to the color of Bag B
1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

29. Which bag is more aesthetically pleasing?
Bag A or Bag B

30. What is your response to the color of Bag C
1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

31. What is your response to the color of Bag D
1 Dislike • 2 Somewhat dislike • 3 Neither like or Dislike • 4 Somewhat Like • 5 Very much like

32. Which bag is more aesthetically pleasing?
Bag C or Bag

APPENDIX B

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

Title of Study: Consumer Perception of Textiles dyed from produce food waste (15427)

Principal Investigator: Dylan Dakota Batch

Faculty Sponsor: Katherine Emma Annett-Hitchcock

<u>What are some general things you should know about research studies?</u>
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of this research study is to gain a better understanding of consumer behavior towards sustainably-produced textile products.

You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those who participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above or the NC State IRB office as noted below.

<u>What is the purpose of this study?</u>
The purpose of the study is to better understand consumer behavior towards sustainably-produced textile products.

<u>Am I eligible to be a participant in this study?</u>
In order to be a participant in this study you must be 18 years old. You cannot participate in this study if you are under the age of 18.

<u>What will happen if you take part in the study?</u>
If you agree to participate in this study, you will be asked to (a) complete an evaluation form consisting of three questions, for four tote bags based on physical appearance, (b) complete a survey related to consumer behavior and sustainability, (c) listen to verbal explanation of dye processes, and (d) evaluate the same four tote bags a second time. Each section should take 5 minutes, with a total survey time of approximately 20 minutes. The study will take place in the atrium located on the first floor of the Wilson College of Textiles on Centennial Campus. No audio or video recording or photography will take place.

Risks and Benefits

There are minimal risks associated with participation in this research. If the participant decides to end the survey prior to completion, all identifying information will be destroyed and their answers will not be included in the study. There are no direct benefits to your participation in the research. The indirect benefits are contributing to the ongoing research in the area of consumer behavior towards sustainable textile products. Participants will gain a further understanding of textile dyeing processes through the verbal explanation above.

Confidentiality

The information in the study will be kept confidential to the full extent allowed by law. No identifying information regarding the participants will be collected other than basic demographic data. Data will be stored securely on a password protected USB drive and will not exist on the third-party application (Qualtrics) or an iCloud. Only the researcher, Dylan Dakota Batch, and the Faculty Sponsor, Dr Kate Annett-Hitchcock will have access to the information. No reference will be made in oral or written reports which could link you to the study.

Compensation

For participating in this study, you will receive a tote bag. If you withdraw from the study prior to its completion, you will no longer be eligible to receive the tote bag.

What if you are a NCSU student?

Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

What if you are a NCSU employee?

Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

What if you have questions about this study?

If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Dylan Dakota Batch, 1020 Main Campus Dr, Raleigh, NC 27606, ddbatch@ncsu.edu, 432-260-6950

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State IRB Office via email at irb-director@ncsu.edu or via phone at 1.919.515.4514. You can also find out more information about research, why you would or would not want to be in research, questions to ask as a research participant, and more information about your rights by going to this website: http://go.ncsu.edu/research-participant

Consent to Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."